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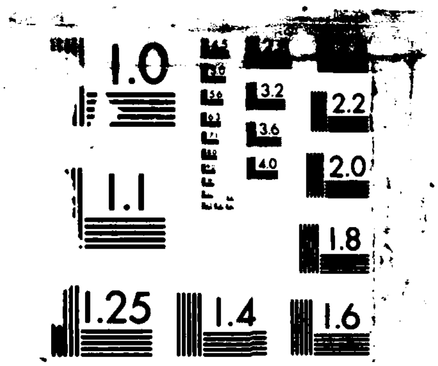

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

AN EVALUATION, REQUIREMENTS ANALYSIS, AND A PROPOSED INFORMATIONAL ARCHITECTURAL DESIGN WITHIN THE MANUFACTURING ENVIRONMENT OF "NORTHERN CALIFORNIA ELECTRONICS (NCE)"

by

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and

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September 1986

Thesis Advisor: Daniel R. Dolk

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This thesis describes the computer resources of a defense contractor and the informational needs within the manufacturing environment of their organization. Since the company wishes to maintain their anonymity, it is referred to as "Northern California Electronics" (NCE). Research is conducted through a series of interviews with department heads and support personnel, observation of work processes, and the examination of current periodical literature and texts. The thesis includes an informational requirements analysis, a proposed informational architectural design, identification and definition of requirement specifications and a description of information systems strategic planning. Keywords;

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An Evaluation, Requirements Analysis, and a Proposed Informational Architectural Design within the Manufacturing Environment of "Northern California Electronics" (NCE)

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ABSTRACT

This thesis describes the computer resources of a defense contractor and the informational needs within the manufacturing environment of their organization. Since the company wishes to maintain their anonymity, it is referred to as "Northern California Electronics" (NCE). Research is conducted through a series of interviews with department heads and support personnel, observation of work processes, and the examination of current periodical literature and texts. The thesis includes an informational requirements analysis, a proposed informational architectural design, identification and definition of requirements specifications and a description of information systems strategic planning.

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I. INTRODUCTION

A. BACKGROUND

"Northern California Electronics" (NCE) is a defense contractor located in the "Silicon Valley" of California. Several months ago its Manufacturing manager, with the approval of the Naval Postgraduate School Academic Associate for Information Systems, recommended that graduate students study NCE's environment as a possible thesis topic. (Prior to beginning our research, top management at NCE granted us their full cooperation.)

Although professional consultants have done studies at NCE, their results have been disappointing and expensive. Because NCE is a project-oriented job shop environment (i.e., they research, design, manufacture and/or assemble one-of-a-kind products), they need an integrated Manufacturing Information System (MIS) which includes a sub-system similar to a Materials Requirements Planning (MRP) system to help them develop a flexible, effective, efficient, timely, and cost-effective centralized information base which satisfies their unique requirements.

However, these systems alone do not provide all the answers to managing production. Since manufacturing is a complex process, it needs inputs and interactions between the many business units of NCE and the departments within manufacturing itself; this means people involvement, management commitment and support at all levels. [Ref. 1:p. 11]. Changes involving the relationship of the organization with their vendors and customers as well as improved communications among other departments within the organization might also be beneficial. When this occurs, MRP presents an organizational-wide view known as Manufacturing Resource Planning (MRP II) [Ref. 2:p. 612].

MRP uses a proactive strategic approach to material management; i.e. it anticipates material needs before they occur and plans for their acquisition: rather than the traditional reactive strategy which waits for customer orders to arrive and then reacts to those orders with material requisitions. MIS, MRP and MRP II are important to management support because they provide the necessary tools for an integrated approach to master scheduling, material requirements planning, and capacity requirements planning. In addition, the MIS facilitates cost control by supplying information for setting standards, and data describing actual operations [Ref. 2:p. 625].

Others aids beneficial to manufacturing include Computer Aided Design (CAD), Computer Aided Manufacturing (CAM), and Computer Integrated Manufacturing (CIM). CAD involves the use of a computer to support the design of everything from bridges to individual parts. The designer is able to move items within the design, as they would in use, to test and detect weak points. CAM, on the other hand, is the application of the computer to those tasks that come after design (i.e., the production of the item) [Ref. 2:p. 616]. CAD/CAM systems can be of strategic importance in planning and management. They can be viewed as any useful combination of the following four technologies:

- Database management
- Computer graphics
- Mathematical modeling (analysis)
- Data acquisition and control (physical prototypes and production processes) [Ref. 3:p. 31].

CIM is a modern concept rather than a technology. It is a management philosophy that attempts to integrate all of the separate computer-based information systems, factory automation, as well as manual information systems [Ref. 4:p. 13]. Since an integrated manufacturing environment includes several business functions such as marketing, finance, administration, research and development, production, plant operations, and planning, there is a need to share information between these functions in a timely manner [Ref. 5:p. 5]. CIM allows managers to look at the firm's production resource as a "single system and defining, funding, managing, and coordinating all improvement projects in terms of how they effect the entire organization" [Ref. 2:p. 618]. As a result, CIM allows managers to view the organization from a systems or macro approach, rather than from a micro approach.

Simply stated, an MIS which may include sub-divisions of CAD/CAM, CIM, MRP/MRP II, is a tool that provides needed information to the manufacturing manager. It is used for monitoring material flow from vendors, through the transformation/manufacturing process, and through delivery of the products, in which both personnel and machines are used to expedite and facilitate this flow [Ref. 2:p. 589]. Additionally, some MIS provide managerial decision support capabilities as well as tracking Work-in-Progress (WIP). However, a unified means of handling routing information, equipment instructions, and test data is needed. A common database should link all this information in order to assure consistency and reduce data corruption caused by human error or machine malfunctions [Ref. 6:p. 15].

B. PURPOSE OF THE THESIS

The purpose of this thesis is to examine the existing computer resources at Northern California Electronics (NCE); study the current Information Management (IM) capabilities; define information flow; specify requirements analysis; determine how data is stored, retrieved and shared; and, through a series of interviews, resolve the needs and desires of management: in particular, those within the Operations Organization which include Manufacturing, Material, Integrated Logistics Support, Technical Data and Controls, and Operations Program Management and Controls.

Most of the interviews take place within the Manufacturing and Material sections of the Operations Organization and involve top-management, middle-management and production support personnel. Emphasis is on manufacturing and material methodologies such as the detailed flow of information among the floor support personnel, the assembly processes, and material requirements. The main sections involved in the analysis are: Walk-In Support, Production Engineering, Test Engineering, Assembly, Manufacturing Planning and Control, Material Support, Physical Distribution, Procurement and Purchasing. Information acquired from these interviews will be used to examine, in depth, processes which take place within these environments.

Fortuitously, most of the personnel interviewed candidly discussed and shared with us their perception of the organizational structure at NCE; the Operations Organization; the existing computer resources available; and, their effect on productivity. Since understanding of the structure of the organization is essential to the development of an informational architectural design within the Operations Organization of NCE, their positive attitude contributes significantly to any success of our study.

It is obvious, that NCE has within its organization (in particular, inventory production control expertise), talented and knowledgeable personnel who can solve most problems as they occur. However, since their time is limited, it is almost impossible for them to take full advantage of their expertise and share it with other departments.

C. SCOPE OF THE THESIS

This thesis focuses on requirements analysis and on the development of a proposed informational architectural design within the manufacturing environment of NCE. However, before beginning this design, it is crucial to be familiar with the underlying structure of the organization. We have accomplished this task, not only by examining organizational charts and literature given to us by NCE; but, also by re-enforcing our perception of the material through follow-up interviews with management personnel. The methodologies used to determine the major activities, informational needs, and processes that occur within NCE include Critical Success Factors (CSF) and IBM's Business Systems Planning (BSP).

D. METHODOLOGIES

CSF is a methodology developed at Massachusetts Institute of Technology whose main emphasis is "helping executives to define their significant information needs" [Ref. 7:p. 16]. We have applied CSF to the NCE Operations Organization in order to identify the key areas in which performance must be satisfied if the organization is to endure and thrive [Ref. 8:p. 330].

Through extensive interviews of management personnel and reviewing company documents, CSF for NCE Operations Organization have been identified. The activities which must go right in order to achieve their objective of manufacturing the best product for the lowest cost in a timely manner include:

- Safety: provide a safe environment and well-maintained equipment allowing employees to perform their tasks efficiently and effectively
- Quality: produce a high quality product which is responsive to customers' needs while establishing a good reputation for NCE to maintain current business clients and obtain future business
- Cost: cost should be competitive with other government contractors; however, the cost of doing business must be lowered in all areas, particularly in labor rate bases and overhead rates
- Schedule: plan for inventory to be received when needed; product should be completed and/or asssembled when indicated; deliverables should be done in a timely and efficient manner

These CSF, as determined from our managerial interviews, could be ideally satisfied in an environment which fulfills the following requirement specifications:

- An efficient and effective integrated interactive on-line computer resource system architecture
- Network management and control
- A cost-effective system
- A system similar to a MIS/MRP II system that is responsive to the needs of a defense contractor "job shop" environment
- A system which provides security facilities (i.e., one in which users can be defined and identified and one in which authorizations can be enforced
- A centralized database (DB)[1] which provides labor and material tracking and exception information as well as a wide variety of access methods (i.e., provides flexibility)

BSP, on the other hand, uses a structured approach which includes the above CSF to help develop a plan for NCE that can satisfy its short and long term informational needs. In addition, BSP's philosophy emphasizes top-down planning and bottom-up design and implementation.

The information gathered from our interviews and from written material and documentation received from NCE is used throughout our study to define the organizational objectives, define requirement specifications, and develop a proposed information systems architecture for NCE Operations Organization.

[1]A database is a "self-describing collection of integrated files. The database is self-describing because it contains, within itself, a description of its structure", known as a data dictionary [Ref. 9:p. 11].

E. DESCRIPTION OF CHAPTERS

Since understanding the organizational structure is essential to the development of a requirements analysis and a proposed information systems architectural design, we begin our study with a review of the organizational structure of NCE as well as the organizational structure of the Operations Organization. An overview of the organizational structure and business objectives of NCE are discussed in Chapter II.

In addition, the existing computer resources available within NCE which include the Information Management (IM) system, the Engineering (ENG) system, and the Office and Engineering System (OES) are described. Further, current capabilities of these computer systems as well as their facility, functionality, major activities and operating costs are reviewed. These areas, developed from information gathered in our interviews and from written material received from NCE, are covered in Chapter III.

Chapter IV is a description of the project and manufacturing processes from bid preparation through delivery of the product. The use of automated systems in the project and manufacturing process are also examined.

In Chapter V, we identify and evaluate the business processes which occur within the Operational Organization of NCE. Business processes are defined as "groups of logically related decisions and activities required to manage the resources of the business" [Ref. 10:p. 30]. Equally important, are the definition and evaluation of business data (entities and data classes). They involve the identification of things or entities (i.e, something of lasting interest to NCE) that are "significant to the business and the grouping of data about these entities into logically related categories called data classes" [Ref. 10:p. 11]. When data classes are identified within the organization, it is easier during the design phase of a system to minimize redundancy. Also, they allow future modifications to be made and systems to be added without having to make major changes to existing systems.

Chapter V also describes the information architecture. The architecture consists of a Process/Data Class Matrix which is used to establish the process/data class relationship. A flow diagram is also developed which identifies the flow of data between process groups and data classes. [Ref. 10:p. 39]. The end product which is the Information Architecture Flow Diagram is a comprehensive management tool. It shows the flow of information throughout the entire organization and helps to identify implementation priorities for NCE. [Ref. 10:p. 45].

The next step is an analysis of the current computer systems support of processes and identifying the use of current data. The output of this is a System/Organization Matrix that displays which departments involved in the processes are getting application support; what percentage of the data classes is currently automated, and which systems utilized which data [Ref. 10:p. 47].

Chapter V also includes the identification and definition of requirement specifications for NCE. Before implementing any system, identification of requirements specifications is important since it is crucial to have a clear understanding of what is needed by the organization.

In Chapter VI, we describe previous NCE system studies, drawbacks of the present environment, and the importance of Information System (I/S) planning.

The final chapter of our thesis presents conclusions and recommendations of our study.

II. ORGANIZATIONAL AND BUSINESS OVERVIEW

A. INTRODUCTION

Northern California Electronics (NCE) is an engineering organization which is program oriented meaning it has the authority and responsibility to fulfill contractual requirements and is authorized to take necessary action for successful accomplishment of a project. The company designs and manufactures sophisticated, customized strategic and tactical electronic systems and products for the U.S. Government. Major revenues of NCE are generated by the research and development (R&D) of these systems. A smaller share of the firms' revenues come from low volume manufacturing in support of R&D and from several follow-on production contracts. In 1985 NCE realized sales revenues of approximately $350 million.

The business growth of NCE is dependent on their ability to capitalize on opportunities for new products created by emergent technologies. The exploitation of these new opportunities involves the use of VLSI[2] and VHSIC[3] technologies for state-of-the-art electronics design techniques and as a base for future products. The production of components incorporating these technologies require a large capital equipment investment. As a result, in the future, NCE may have to depend on external sources for development, design, production, and assistance in the application of these components. [Ref. 11:p. 3]

Due to its heavy dependence on government contracts, NCE is very sensitive to the implications of a reduction in defense spending. Historically, cuts in defense budgets have impacted R&D programs first; another occurrence could affect NCE's major revenue producing activity. In such a situation, the manufacturing activity must assume greater importance since the production of reliable systems and components should continue to increase if the company is to maintain their high standard of quality and profitability.

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[2]VLSI refers to Very Large Scale Integrated circuit which contains over 10,000 logic gates on a chip.

[3]VHSIC refers to Very High Speed Integrated Circuits used in signal processing systems.

The implication for automation within the Operations Organization is that any Manufacturing Information System should be designed to support the current project-oriented manufacturing process, but also have the ability to adapt to a more production-oriented manufacturing process. [Ref. 11:p. 5]

B. ORGANIZATIONAL STRUCTURE

There are two major business areas within NCE supported by a number of staff and service organizations. These major business areas are Strategic Systems (SS) and Tactical Systems (TS). They are involved in the research, design, development and manufacturing of strategic reconnaissance, electronic warfare, and electro-optical systems.

The SS business area is responsible for acquisition and program performance on programs in the organization that include all systems and studies procured by:

- National Agencies
- Fixed-site systems procured by Department of Defense (DOD)
- Special access systems
- All export systems in the organization's technological areas [Ref. 12:p. 13].

The TS business area is responsible for all programs that involve systems for mobile platforms, ground/airborne collection and processing, and tactical intelligence collection and analysis. TS is also accountable for electronic design and development of transmitters within NCE. They provide mechanical engineering capability, maintenance, and training support. [Ref. 13:p. 5]

Together these organizations are supported by a staff of approximately 3200 employees including approximately 1700 engineers and scientists. NCE's physical plant consists of seven primary buildings as well as a number of smaller facilities.

Both the SS and TS directorates contain a research and engineering organization to ensure emphasis on technology as the foundation of NCE's business strategy. These organizations are staffed with people who have extensive experience in designing and implementing software and hardware as well as equipment engineering and support functions. The engineering groups are designed to provide effective participation of all engineering functions in the early phases of new program development. In addition, SS and TS have marketing and programming staffs to effectively carry out their assigned missions. [Ref. 13:p. 8]

The major business areas, SS and TS, are supported by a number of service and staff organizations which include:

- Operations (Manufacturing)
- Quality Control
- Digital Systems
- Chief Engineer
- Comptroller
- Personnel
- Administration
- Business Development and Planning

The key organizations involved with computer resources are the Strategic Systems Directorate, the Comptroller, and Digital Systems. The Strategic Systems Directorate operates a computer center which supports engineering research and development. The Comptroller operates a computer system which supports the business and administrative functions of NCE. The Digital Systems Department, through its Office and Engineering System (OES), serves as an interface between the engineering and business systems.

C. PROGRAM MANAGEMENT

NCE has established program organizations dedicated to particular projects to ensure that contract schedules and costs are met. NCE is organized under the matrix model as shown in Figure 2.1. A matrix organization is one in which

> Managers of each functional department look vertically and concentrate on obtaining functional effectiveness (i.e., efficient production). Program managers look horizontally and concentrate on seeing that program needs are met (program effectiveness). Operating individuals are subject to the direction of both managers [Ref. 14:p. 79].

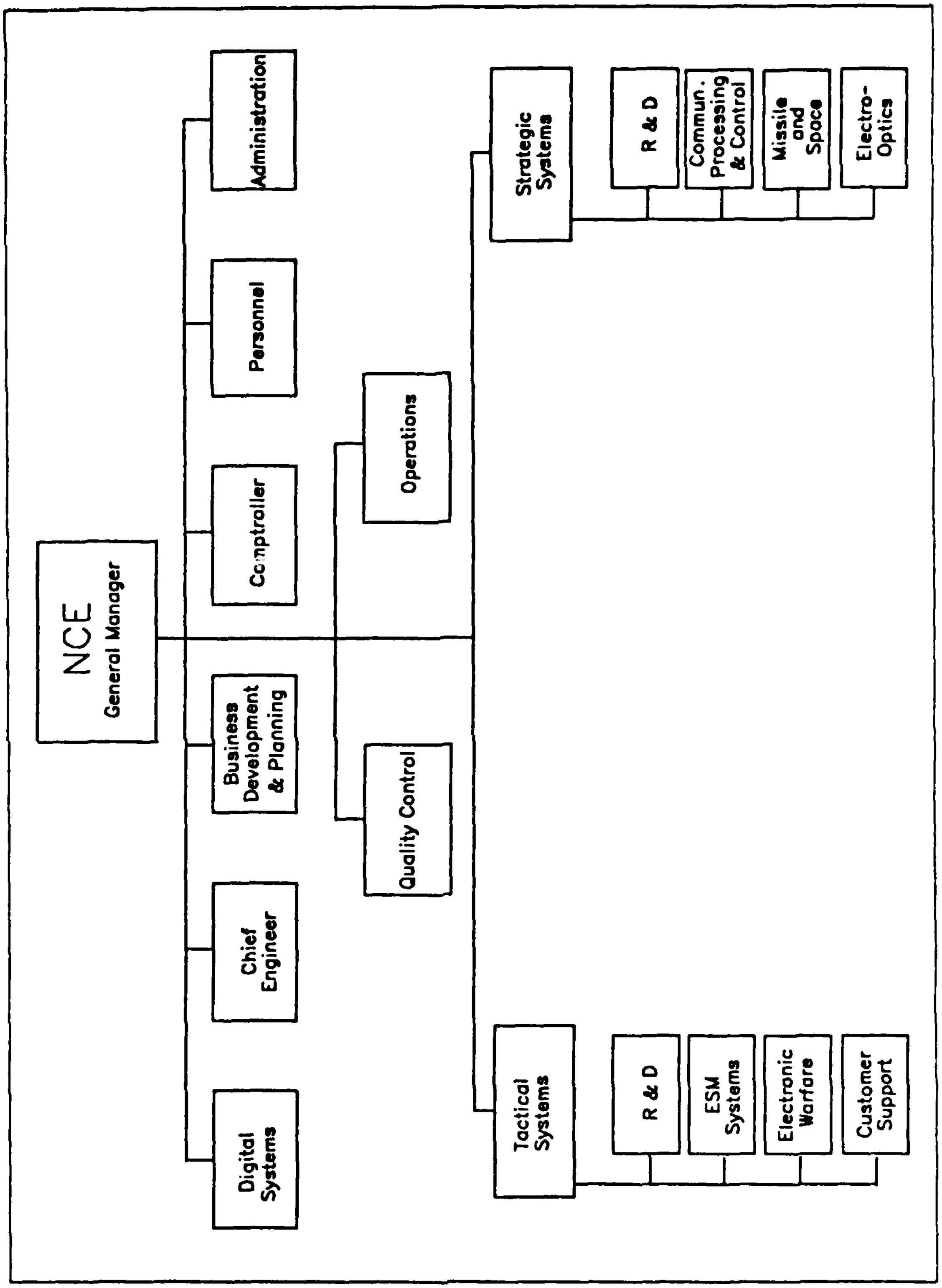

Figure 2.1 Organizational Structure of NCE

This structure is very appropriate for NCE. It favors program managers, managerial groups, and functional departments since it allows them to share information and collaborate decision making on vital programs. The project management organization within NCE consists of a Program Manager (PM) and representatives from Product Assurance, Subcontracts, Cost Control and Contracts. Other personnel may be assigned to the PM according to program needs.

NCE authorizes and controls work through the use of a work authorization document. These documents are issued by the program office and they assign discrete work packages to organizations within NCE. Work authorizations describe the segment of work to be accomplished within established schedules and budgets. They form agreements between the program organization and the assigned responsible individual or functional organization.

Only with the issuance of work authorizations may work be performed at NCE. Work authorizations include a detailed description of the task to be accomplished, schedule of performance, funds budgeted and authorized to the responsible person, reporting requirements, and the performing organization. The work authorizations form the basis for planning all intradivisional work performance for the completion of any contracts. It is against these plans that actual program progress is monitored and reported.

By acceptance of the work authorization, the assigned or functional task manager is responsible for the performance, cost, and schedule of the given task. Breakdown to a subtask level requires further agreements between the task manager and supporting organizational groups. These agreements are reached with the concurrence of the PM although the task manager remains fully accountable to the PM for the entire process.

D. NCE MANAGEMENT SYSTEMS

The design of NCE management systems are governed by the necessity to meet special requirements that facilitate the control and auditing of all work done under contract for the U. S. Government. These requirements are established by the Cost Schedule Control System Criteria (C SCSC).

C/SCSC establish special requirements in the areas of budgeting, earned value development analysis, and data traceability. These criteria must be met in all phases of a contract: from the research and development phase through the production phase.

In a manufacturing environment, key requirements of C/SCSC are the integration of a Work Breakdown Structure (WBS) and Bill of Materials (BOM) (a form of which is a Summary Parts List (SPL)).

A WBS is a system which organizes, defines, and graphically displays, in a hierarchical manner, the tasks to be completed in order to produce a given product. Of course, the WBS is directly influenced by the product to be constructed. Thus, the BOM is critical to this process. The BOM is the document which defines the product being built in terms of components in each assembly and sub-assembly. It is originally created as part of the design process. The BOM is then used by manufacturing engineers to determine which items should be bought and which items should be fabricated.

When the WBS and BOM are integrated, the result is the development of discrete work packages which identify the tasks and materials necessary to produce a required output. These work packages, in turn, associated with required product delivery dates, drive the scheduling of work and ordering of parts.

The cost account is the controlling point for planning, budgeting, and collecting costs. It represents efforts to be performed by one responsible organizational manager on one contract WBS element. Budgets for cost accounts are planned and identified in terms of labor hours, labor dollars, material, subcontracts, and other direct cost dollars. Cost and schedule performance responsibility for each cost account is assigned to a Cost Account Manager (CAM).

E. COST AND PROGRAM CONTROL

The basic unit of cost collection at NCE is a seven-digit charge number which consists of two blocks of numbers. The first block of three digits contains the contract prefix identifier. All costs collected against this identifier are summarized and billed to the applicable contract. The second block of four digits is used to identify a discrete task within the given contract. Thus, the overall contract is identified by the prefix digits while the work order number correlates to the Work Breakdown Structure (WBS).

Through this method, the cost data is automatically accumulated in accordance with the WBS using the NCE Information Management (IM) system. This system provides the ability to assign up to 9999 tasks with total visibility of cost and schedule for each task. The charge numbers are used to identify labor, material, subcontracts, and other elements of costs. The elements of cost are accumulated against a common set of assigned charge numbers as shown on the WBS, Bill of Materials (BOM), and work authorization forms. NCE's accounting systems record actual cost incurred and committed on a weekly basis and also provides budget comparisons. Tasks are summarized by the IM computer in various weekly cost reports.

Program control is maintained using the Program Control System (PCS). It is used to plan and apply corrective action when necessary and to measure monthly performance. Each open task is measured in terms of budget, schedule, and work accomplished. Significant variances in plans are highlighted for management in monthly reports. Variances are explained and corrective action is taken. A full program status and schedule report is prepared each month showing financial and schedule status of programs

F. COST ACCOUNT

A CAM is a manager at any level of the organization who is responsible for management of a specific task. A CAM may have control of more than one cost account. He uses two primary tools for the planning of work, under his supervision, on a particular contract; a planning package and a work package.

All work to be accomplished for a given contract is covered by either a planning package or work package. A planning package is designated by a seven-digit charge number; it is this portion of the cost account effort which is too far in the future to be identifiable by a detailed work package. Converting a planning package into a work package is governed by a concept called the "Planning Horizon". The Planning Horizon is 26 weeks from the current date. Any work scheduled to occur more than 26 weeks from the current date is accounted for in the planning package. As the time for the work covered by a planning package moves within 26 weeks of the current date, the planning package is converted into a work package.

A work package, also designated by a seven digit charge number, is a discrete subtask of the cost account. It represents the lowest level task or job assigned within a cost account for which performance can be measured. A work package has the following characteristics:

- It is planned by the company
- It represents unit of work levels where work is performed
- It is clearly distinguishable from all other work packages
- It is assignabie to a performing organization
- Its uuration is limited to a relatively short time
- It has scheduled start and completion dates
- It has a budget or assigned value expressed in terms of dollars, manhours or other measureable units
- It is integrated with detailed engineering, manufacturing, and other schedules.

The CAM's execution and control of work for a given contract is governed by work authorizations: there are two types, interim and firm. An interim work authorization is issued unilaterally by the PM to initiate work while work statements, schedules, and budgets are being developed. They provide the budget and authority to perform work for no more than a two month period. The firm work authorization is used by the PM to delegate responsibility to the functional or cost account manager for budget, schedule, and task requirements. A work authorization accomplishes the following:

- Allows the opening of the cost account effort
- Provides an agreement between the tasking authority and the functional organization performing the work
- Establishes overall schedule, total budget, and amount authorized at the cost account/work package level
- Defines the functional statement of work
- Establishes and assigns responsibility

G. ORGANIZATIONAL STRUCTURE OF OPERATIONS

The main objective of Operations is the timely and profitable fulfillment and productivity of NCE's hardware, material, and documentation requirements. Also, as stated in the introduction, quality is a CSF. It has been defined by management as being the attribute of goods produced which affect its perceived value (i.e., correctness, reliability, and useability). With this concept in mind, the Operations organizational structure is shown in Figure 2.2. It consists of the following departments:

- Integrated Logistics Support (ILS)
- Technical Data and Controls (TDC)
- Material
- Manufacturing
- Program Management and Controls (PMC)

Within ILS, Reliability Engineering (RE) evaluates test data produced during the assembly process as well as data produced during customer use of the end item. Based on these evaluations, engineers isolate the problems which may be found in parts, system design, or assembly and they attempt to improve them. RE helps to ensure the readiness of operational systems. This includes the integration of reliability, maintainability, and logistics analyses into equipment design and development of economical support concepts for reduced system costs.

Drafting, with the aid of a CAD/CAM system, develops the designs which are used in guiding the assembly process and for the supporting technical data and control. CAD/CAM system objectives is to improve product quality and reliability with cost-effective manufacturing.

Material, with the aid of the MIDAS database (discussed in Section D: Applications Used by Operations), produces estimates on material costs, purchasing materials and stocking the material used in the production process.

Program Management and Controls monitors the cost and schedule of programs in Operations to ensure requirements are being met.

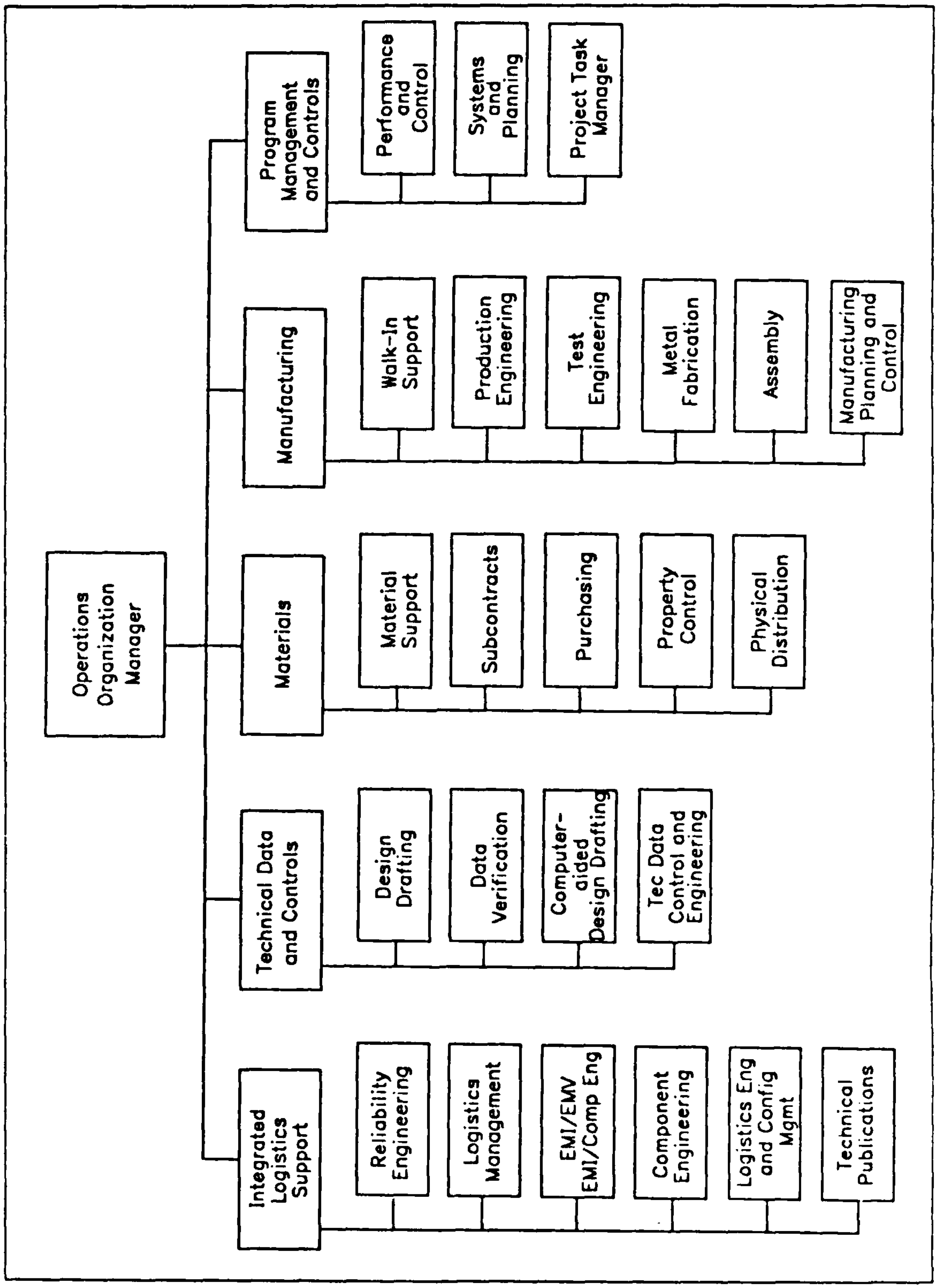

Figure 2.2 Organizational Structure of Operations

Manufacturing, which is the department within Operations on which our study focuses, is responsible for producing and/or assembling systems. There are 124,300 square feet of manufacturing facilities containing a modern metal workshop, a microelectronics fabrication facility, a work flow oriented electronics assembly facility, and two buildings dedicated to vehicle and mast programs.

The manufacturing strategy of NCE is that of an assembly house with procured sub-assemblies and components. This strategy is designed to improve performance and responsiveness for building high quality equipment with fast turnaround, while trying to maintain a flexible and cost-effective operation. Through the use of factory automation and computerized techniques, processes may be done more efficiently and effectively.

Although mainframe computer support for some of Operations' processes is provided by the IM system, the Manufacturing Department has begun to automate additional processes through the use of personal computers. Applications, using database and spreadsheet programs, have been developed on personal computers (PCs) to track and analyze manufacturing data. In addition, computer applied time standards and computer generated shop orders allow for more reactive capability to meet program requirements and time schedules.

Operations is currently looking at ways to improve their productivity within manufacturing. These include:

- The evaluation of manufacturing process automation techniques
- Computerization of manually maintained information
- Automated manufacturing controls
- New material management systems and techniques [Ref. 11:p. 3].

III. OVERVIEW OF THE EXISTING COMPUTER RESOURCES

A. INTRODUCTION

Computer resources at NCE are administered by one of three organizations; the Information Management (IM) system, which is subordinate to the Comptroller; the Engineering (ENG) system which is subordinate to the Strategic Systems directorate; and the Office and Engineering System (OES) which is a responsibility of the Digital Systems Department.

NCE has approximately 2500 computer users in support of a total work force of approximately 3200. The percentage of computer users by organizations is shown in Table 1.

TABLE 1
PERCENTAGE OF COMPUTER USERS BY ORGANIZATION

Organization	**Computer Users**
Engineering Directorates	54.0 percent
Operations	19.2 percent
Administration	9.1 percent
Finance	8.2 percent
Quality Assurance	3.6 percent
Human Resources	2.5 percent
Business Development	1.8 percent
Proposal Center	1.6 percent.

B. THE IM SYSTEM

1. Background

The IM organization is the oldest of the three computer organizations at NCE. As in many companies, the computer was used initially as an accounting tool and naturally fell under the auspices of the Comptroller. As technology has progressed and computer applications have become more versatile and widespread, other organizations within NCE have become users of IM. Presently, this has resulted in the IM department supporting Operations (manufacturing), Administration, Quality Control, Personnel, Business Development, the Proposal Center and some aspects of Engineering as well as Finance.

In total, the IM department supports approximately 800 NCE employees. It currently employs a staff of 55 including 19 applications staff, 34 data center staff, and 2 managers. To recover some of its operating costs, the IM department employs a chargeback system which bills its customers for computer services. The department is currently implementing a new vendor-supplied chargeback system known as JARS. The IM department at one time provided all computer support to the Engineering Directorates but demand became so great that another computer center was established which was dedicated to engineering research and development.

Due to the length of time that the IM department has been in existence, many of its applications are old and run in a Multiple Virtual Storage (MVS)[4] batch-oriented environment. This capability still satisfies many requirements. However, because of the age of the applications and changing needs of many users for more responsiveness, on-line support, and networking capabilities, the IM department has begun to move in the direction of adding an interactive Virtual Machine (VM)[5] operating system to its existing computer resources.

Several years ago, during a company-wide resource cutback, the IM department's budget was frozen. This freeze lasted a year during which no new projects were initiated and system development basically stopped. The IM department

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[4]MVS is an operating system that supports multiple tasks, each with its own virtual address space. [Ref. 15:p. 55]

[5]VM is an operating system that allows multiple copies of most operating systems to run under it by simulating a separate machine for each suboperating system. [Ref. 15:p. 56]

has yet to recover from this setback and currently has an applications development backlog of 17,000 manhours.

2. Computer Resources

The IM department has an IBM 3083B with a computing power of 6 Million Instructions Per Second (MIPS). The 3083B system contains 16 Megabytes (MB) of main memory with plans to upgrade to 24 MB in the 1986-87 time frame. Printed output is provided by a XEROX 9700 Laser printer and three impact printers as well as a plotter. Input/Output (I/O) is possible through any of the following media:

- 16 Gigabytes (GB) of DASD (will increase to 30 GB in 1986)
- 8 magnetic tape drives
- Punch card
- Paper tape

Normal user access is via 275 hardwired terminals serviced by 56 line printers. In addition, this system is tied into a corporate product information network with international access. The 3083B is capable of supporting 200 simultaneous users and is accessible to 600 people. Costs associated with the IM computer resources are shown in Figure 3.1.

	1984	**1985**
Operating Costs:	$4.29 Million	$4.67 Million
Labor Costs:	$2.03 Million	$2.20 Million
Total Costs:	$6.32 Million	$6.87 Million

Figure 3.1 IM System Costs for 1984 and 1985

3. Functions and Applications

Currently, the IM department's major project is development of an Integrated Financial Forecasting Reporting Management System (INF^{2}ORM). This project features on-line access to the financial DB; on-line maintenance capabilities; extensive editing and error handling facilities; audit trail of accounting information; and, extensive reporting capabilities. The project started approximately two years ago and is projected to continue for another three years; it is a first attempt at centralization, (i.e. although inputs come from several sources, its management is under the control of one DB).

The IM department supports more than 50 applications, some of these are on-line systems but the majority are batch-oriented programs. The IM department also supports an IBM MVS Time Sharing Option/Interactive System Productivity Facility (TSO/ISPF) which is the facility that gives MVS interactive terminals and a menu-oriented program development aid. [Ref. 15:pp. 55, 56]

Approximately 450 employees have TSO log-on capability and the 3083B currently supports 60 concurrent users. TSO presently accounts for 53 percent of prime shift and 29 percent of total utilization. Major users are Finance/Proposal Center with 40 percent, IM with 25 percent, Engineering with 20 percent, and Manufacturing with 13 percent.

The computer resources at NCE are primarily used in support of seven functions. These functions are management, documentation, office automation, design, information, proposals and communications. For purposes of comparing the relative use of the IM system for each of these functions, a scale of high, medium, or low is used [Ref. 16:pp. 30-34] and is shown in Table 2.

A major IM department initiative is the establishment of an Information Center (IC). The concept of the IC is to extend IM capabilities to the user community by immediate information access. The approach of the IC is that users implement their own applications; however, assistance is also provided including hot lines, person to person communication; and consultants. Applications consulting and training is the focus of the IM IC. Training will involve systems application, tools, and database utility and functions. The applications available within IM to support the seven functional uses of the NCE computer resources are shown in Figure 3.2.

TABLE 2
FUNCTIONS AND THEIR DEGREE OF USE WITHIN IM

Functions	Degree of Use
Management	High
Documentation	Low
Office Automation	Low
Design	Medium
Information	Medium
Proposals	High
Communication	Medium

RAMIS, a 4th generation data management and report generation DB, is the primary IC tool to optimize costs as well as maximize functionality and security since it is mainframe based. It is easy to use since it is menu-driven, has english-like commands, and can be used with TSO data, MIS, C/SCSC and existing financial systems. The IC can support cost effective use of office automation and end-user computing in the mainframe and in the personal computer environment. IC operating costs for 1986 are estimated at $230,000.

C. THE ENGINEERING SYSTEM

1. Background

The Engineering System was established in 1975 when engineering computer support was separated from the IM department. The impetus for this move stemmed from the growing demands of software development associated with the increasing use of microprocessors in NCE products. Efficiency in this process required an interactive environment, and, processing volume indicated the need for a separate system. Engineering research and development's leading role in NCE operations resulted in this new resource coming under the cognizance of Strategic Systems.

MANAGEMENT

INF^{2}ORM
MCS
MIDAS
Logistics
PMS4
MTS
Shop Order Status (SOS)
Admin Systems
Quality Assurance

INFORMATION

RAMIS
ADR/QUERY
SYS W
GDDM
Multiple DBMS:
  ADR: INF^{2}ORM
  S2000: MIDAS
  IMS: CSPEC
  RAMIS: INFO CENTER
Data Dictionary
Data Security (ACF2)
Disaster Recovery

OFFICE AUTOMATION

GDDM (Graphics)
Telephone Directory

COMMUNICATION

GTE Network
Hardware Terminals

DOCUMENTATION

Manuals (TSO)
Specifications (TSO)
Purchase Orders
Provision Lists

DESIGN

AD/CAM INterface
Simulation
Modeling
Circuit Analysis
ADR/IDEAL
Compilers

PROPOSALS

COSTR
Material Estimating
PEARS (Vax) Interface

Figure 3.2 Relationship of Functions to IM Applications

Over a period of time, other applications were placed on the Engineering System. Currently, it also supports word processing, CAD/CAM systems, and office automation. The preponderance of engineers in the organization (60 percent) has resulted in the Engineering System supporting far more users (approximately 1700) than the IM department. There is no chargeback system on the Vax since it is supported by capital funds of the company. It is, therefore, a very popular resource.

2. Computer Resources

The core of the engineering computing resource is a cluster of five Digital Equipment Corporation (DEC) Central Processing Units (CPU). They are connected by a Star[6] coupler[7] which has the capability of supporting up to 16 devices.

Four of these CPU's are Vax 11/785's rated cumulatively at 4 MIPS while the fifth CPU is a Vax 8600 rated at 4.2 MIPS. The total system has 72 MB of main memory.

I/O is accomplished via 7.4 GB of Direct Access Storage Devices (DASD) and 6 magnetic tape drives. Printed output is available via three local impact printers and 12 remote printers. 360 terminals are connected to the system via telephone switches and 320 terminals are connected via an Ethernet Local Area Network (LAN).[8] The engineering system is capable of accessing wide area communications via a company information network, a computer science network, and MILNET which is the unclassified section of the Defense Data Network (DDN). Costs associated with the ENG computer resources are shown in Figure 3.3.

	1984	1985
Operating Costs:	$ .82 Million	$ .951 Million
Labor Costs:	$ .20 Million	$ .280 Million
Total Costs:	$1.02 Million	$1.231 Million

Figure 3.3 Engineering Systems Costs for 1984 and 1985

[6] A Star is a type of topology or structure, consisting of paths and switches, that provides communications interconnection among nodes of a network. [Ref. 17:p. 356]

[7] A coupler is a central switch which allows communications between and among CPUs for data transmission. [Ref. 18:p. 9]

[8] A LAN is a communications network that provides interconnection of a variety of data communicating devices within a small area. [Ref. 17:p. 354]

3. Functions and Applications

Within the engineering department there is also office automation and an electronic mail (EM) system. The EM is used extensively for inter-office communications. (It comes with the operating system on the Vax.) The Vax, which was first used for software development, facilitates all of engineering. However, it has grown to support other functions as well as other departments and groups. The documentation function on the Vax is used the most. The seven functions supported by NCE computer systems and their degree of use within the ENG environment are shown in Table 3.

TABLE 3
FUNCTIONS AND THEIR DEGREE OF USE WITHIN ENGINEERING

Functions	Degree of Use
Management	Medium
Documentation	Medium
Office Automation	Medium
Information	Medium
Communication	Medium
Proposals	Medium
Design	Medium

The engineering system currently has a staff of nine people; three systems operators; a secretary who acts as a liaison between the systems applications and the user community; as well as system programmers and analysts. They provide engineering support for software, networking, and design applications. The applications available within engineering to support the seven functional uses of the NCE computer resources are shown in Figure 3.4.

MANAGEMENT

Budgeting:
- C CALC
- Salary

Schedule:
- VISION

Control:
- CSSR:
- TRACKER

Forecasting:
- MARS

Estimating
- PEARS
- SPAM

DESIGN

Software:
- Program Support Environment (PSE):
  - Language Sensitive Editor (LSE)
  - Graphical ADA Design System (GADS)
  - Source Line of Code Counter (SLOC)
  - Mathematical Library (IMSL)
  - PDL
  - Coding:
    - ADA Fortran
    - Pascal ASM 86
    - C Basic

Firmware Support Environment
- Attached MDS

Electrical:
- Circuit Simulator (SPICE)
- Modeling Utility (ACSL)

OFFICE AUTOMATION

Text Processing:
- EDT
- SCRIBE
- Runoff

Graphics:
- DEC SLIDE
- DEC GRAPH
- DATA TRIEVE

File Management: MVS
- VMS
- Archive

Telephone:
- Phone
- Telephone Book

COMMUNICATION

Wide Area:
- Corporate Network
- Computer Science Network
- MILNET

Local Area
- Ethernet/DEC NET

Switch
- INFOTRON

Gateway
- SNA

INFORMATION

Data Management:
- DBMS
- RDB
- RIM
- DATA TRIEVE

DOCUMENTATION

Text Processing:
- EDT
- SCRIBE
- RUNOFF

Forms and Tables:
- TDMS
- FMS
- TABLES

PROPOSALS

Estimating:
- PEARS
- COSTR

Figure 3.4 Relationship of Functions to ENG Applications

The goal of Engineering, like IM, is to meet their users' needs and requirements as effectively and efficiently as possible; consequently, there is also a large demand for usage of the Vax. Normally, the staff can satisfy requests within a two week time frame.

D. THE OFFICE AND ENGINEERING SYSTEM (OES)

1. Background

The OES organization operates under the auspices of Digital Systems. OES serves as an interface, to some extent, between the IM and Engineering resources. Planners in this organization develop proposals for upgrades or new applications and circulate them to other departments at NCE. OES is responsible for planning and implementing computer networks within buildings and between buildings at NCE; for establishing communication between the IM (IBM) and Engineering (Vax) mainframes; and, for the acquisition and support of personal computers and specialized computer-based systems. Additionally, the Digital Systems Department is responsible for evaluating software for potential application in support of NCE's needs.

A significant responsibility of the manager of Digital Systems is as staff advisor to the General Manager for issues concerning NCE's computer resources and architecture. A major issue is the coordination of the development of a total computer system architecture.

2. Computer Resources

A part of Digital Systems responsibilities entail the establishment of a rational plan for the development of communications networks linking the various computer resources of NCE.

Presently the IBM mainframe is linked to remote terminals and PCs through an ad hoc network which uses telephone lines. This network has been created in piecemeal fashion over time. The Vax engineering mainframe and IM IBM mainframe are linked via a Systems Network Architecture (SNA) gateway; (i.e., a node or switch that permits communication between two dissimilar networks) [Ref. 19:p. 358]. However, this connection is primitive and beyond the comprehension of the average user.

Users can access the IBM from the Vax, but cannot access the Vax from the IBM because of security considerations. There is a converter node that is in the process of being attached from Ethernet to the IBM which maps the keyboard and converts EBCDIC[9] terminal input to ASCII[10] and vice versa. However, IBM users still cannot access the Vax unless a pipe connection is established between the Vax and the IBM.

The converter node and pipe connection could be avoided if VM, as planned, is included as a system node on the IBM mainframe. VM has several software packages, such as the Remote Spooling Communications Subsystem (RSCS) network. RSCS is an operating systems that runs under the control of VM/370. It allows communication not only between MVS and VM, but also between different computer systems. Consequently, with RSCS as a system node, communications via Ethernet is possible between the IBM and the Vax and visa versa with the installations of controllers. [Ref. 20:p. 1-2]

RSCS is dedicated to accepting files and transmitting these files to the appropriate users; or, re-transmitting these to the destinations specified by the files' submitters. Additionally, commands and messages can also be communicated in both directions. Files or messages can be received via a virtual reader even if the receiver is not currently logged on to the system. [Ref. 20:p. 1-3]

In addition to the IBM and Vax mainframe, NCE currently has 550 APPLE PCs, 250 IBM PCs, XTs and ATs, and 51 DECMATES with approximately 100 or more PCs on order. They also have stand alone and networked work stations. These microcomputers are serviced by 430 printers. Costs associated with the OES computer resources are shown in Figure 3.5.

3. Functions and Applications

Since users see immediate results and feedback with the usage of PCs, they are popular within NCE. However, when first introduced in 1981, the learning curve reduced manufacturing productivity almost 20 percent when compared to the previous

[9]EBCDIC refers to Extended binary-coded decimal interchange code. A codes character set consisting of 8-bit coded characters. [Ref. 18:p. 142]

[10]ASCII refers to American National Standard Code for Information Interchange among data processing systems, data communication systems, and associated equipment. The ASCII set consists of control characters and graphic characters. [Ref. 18:p. 23]

	1984	1985
Operating Costs:	$0.88 Million	$2.88 Million
Labor Costs:	$0.50 Million	$0.50 Million
Total Costs:	$1.38 Million	$3.38 Million

Figure 3.5 OES Systems Costs for 1984 and 1985

year. This is not surprising since it takes time to gain familiarity with the PC systems and their applications. As a result, some departments were encouraged to use the mainframe applications. Nevertheless, usage of PCs has increased tremendously, and with heightened familiarity, productivity has increased as well. The relationship of the seven NCE functions, using stand alone PCs, and their degree of use within the OES environment are shown in Table 4.

TABLE 4
FUNCTIONS AND THEIR DEGREE OF USE WITHIN OES

Functions	Degree of Use
Management	Medium
Documentation	Low
Office Automation	Medium
Design	Low
Information	Low
Proposals	Low
Communications	Low

OES is responsible for networking the mainframes and terminals. Currently the major networks are Ethernet, a Local Area Network (LAN), that services the engineering mainframe; and, a telephone switch through which PCs are linked to the engineering mainframe. It is typically used for terminals, microcomputers, and minicomputers. Stand alone PCs and work stations are in the process of being networked through the LAN. When this is completed, information sharing will be possible and will provide a less isolated environment. The applications available, using stand alone PCs, within OES to support the seven functional uses of the NCE computer resources are shown in Figure 3.6. Eventually, PCs as well as work stations will be networked via the OES switch and the OES LAN.

MANAGEMENT

Budget:
- LOTUS 1-2-3
- MULTIPLAN

OFFICE AUTOMATION

Graphics:
- FutureNet
- MacDraw
- MacPlot

Desktop Management
- SPOTLIGHT
- MacDesk Accessories

INFORMATION

Data Management:
- DBASE III
- REFLEX
- FILE

COMMUNICATIONS

OES Telephone Switch
OES LAN

DOCUMENTATION

Word Processing:
- SAMNA III
- WORD

DESIGN

Software Code:
- Code
- Basic
- Cobol
- Pascal
- Others:
  - Think Tank
  - SAVVY AI System

PROPOSALS

To be determined

Figure 3.6 Relationship of Functions to OES Applications

Digital Systems main goal is to have a networked environment which treats NCE's computer resources (IM, Vax, and OES) as a total systems architecture rather than as independent islands.

E. APPLICATIONS USED BY OPERATIONS

Since the focus of this thesis is on the Operations Organization, a short description of the applications used within their business environment is provided. Operations uses several automated application programs in the manufacturing process which are supported by IM systems.

The *MATERIAL ESTIMATING SYSTEM* (MES) allows the proposal center to price material based on historical data supported with current vendor quotes. ***PEARS*** is an on-line system used for labor bidding. ***COSTR*** is a labor and material pricing system which takes the labor hours from PEARS and the material dollars from MES and applies labor base rates and overhead costs to price the proposal.

MIDAS, the Material Information Data Acquisition System, is a DB which offers on-line access; maintenance; and screens as well as batch reporting in support of:

- Engineering data control
- Material procurement
- Incoming inspection
- Material control

The engineering data control subsystem produces cost parts lists, indented parts lists, kit lists, item masters and project structures. Material procurement encompasses the procedures, methods and data required in the completion of material-related functions beginning with the proposal and quotation process of procurement and proceeding through the delivery of usable materials to inventory Stores. Incoming inspection deals with the evaluation of vendor-supplied lots of material. Material control includes the methods and data required to maintain accountability of stock within inventory Stores.

ISLIP is a system which monitors and processes deliverable end-items of large fixed-priced U.S. Government contracts. This system begins with the initial award and tracks modifications during the life of the contract. When each deliverable end-item is ready to be shipped, the system monitors the Request For Shipment (RFS), the inspection Final Quality Assurance (FQA) and the shipment of the item. During this time a Shipping Order Form (DD250) is printed out. The shipped line items are then automatically invoiced in a nightly batch run. This batch run also feeds the corporate accounts receivable system.

There are two logistics systems: ***Logistics Provisioning System*** developed in-house; and, a ***Logistics Support and Reporting System (LSAR)***, developed by the United States Army. These systems generate numerous reports including:

- Product structures
- National stock number index
- Part number index
- Critical maintenance task lists

The ***PMS IV*** system is used for master scheduling and project management. Currently it is being used in conjunction with Easy Pert (graphics) and Vision (as a back-up) to provide some developmental capability in these areas.

The ***Material Tracking System (MTS)*** is an in-house system developed for contract material scheduling. This system has been required for use on some Air Force contracts. While it has been a useful tool, it requires frequent 'tuning' for optimum performance. The implementation of MIDAS has almost completely replaced this system and it is currently not in use.

Shop Order Status (SOS) is a TSO file on the IBM mainframe. SOS is a tool used at the option of production support personnel for recording critical milestones in the assembly phase of a project. This file does not interface with any other and it's use varies from project to project.

The ***Management Control System*** (MCS) is a key application for NCE since it is has been validated as fulfilling C/CSCS criteria by the federal government. MCS is used for planning, budgeting, organization, and work analysis. The system tracks data such as, variances, inputs from production control, time frames of deliverables, and material control. MCS is required for use on some government contracts that exceed certain manhour and dollar thresholds and is voluntarily used on many more. Due to the large overhead costs associated with use of the system, it is used internally only on firm fixed-price contracts of $5 million or more.

The *Labor Tracking System* (LTS) is a historical database which has been in use since 1968. A primary use of this database is as a source of information for developing the labor portion of a bid for a repeat order. LTS also generates a weekly labor tracking performance report for ongoing projects. LTS uses a seven digit project task number as its primary search key for tracking repeat jobs. The system also tracks by part number, and charge number or work center number. The primary source of data for LTS is the timecard. The data from the timecard is usually input on Friday, processed over the weekend and available by Monday or Tuesday of the following week.

The *Cost Accounting Report* (CAR) system contains information based on timecard input which is used to create various cost, schedule, and performance reports.

F. SECURITY OF COMPUTER RESOURCES

1. IM Security Systems: Physical and Software

Entrance to the IM computer system is protected by a cipher lock. Access can only be gained by employees who are given an entrance card to the cipher lock and have a need to be in the area. Since the IM computer system does not handle classified computing, the cipher lock provides sufficient security for its resources. However, there is a need to protect data on their system from unauthorized users. The software security available on the IBM mainframe is known as ACF2. It acts as an enhancement to IBM's MVS and VM operating systems.

ACF2, as stated by Edwards in his article "Data Processing Security and Control," provides implicit protection (i.e., using a data base of algorithmically defined access rules, it protects all data by default.) In order to access data sets, the user must take specific actions in order to "unprotect" data and allow sharing. Program paths are protected from the user since he must qualify for a higher level of access when using a particular program or set of programs. Additionally, ACF2, intercepts the allocation, update, scratch, open, and catalog processing of new and old data sets and determines if access is allowed.

Access can also be restricted by input sources such as department or application through log-on IDs. Production jobs are usually associated with a a department or application system, which sometimes is the case at NCE, rather than with an individual. Therefore, ACF2, seems to be an adequate security system for NCE's IM environment. It protects production log-on IDs through a restricted attribute capability that prevents their use by individuals and restricts their use to specific job submission paths.

ACF2 also controls system access through user passwords which are stored in the ACF2 data base in a one-way (i.e., nonreversible) encrypted format based on the time of day that the password was set and on the password itself. Since the password is stored in encrypted form, the only option available when a user forgets his password, is for the security manager to set a new one. ACF2 also provides audit and reporting tools which allows the security manager to monitor and record security-related activity. [Ref. 21:p. II-G-2]

Since ACF2 protection is based on algorithms, system overhead is minimal. All CPU time, based on benchmark[11] tests, with all systems resources protected is less that 0.5 percent. Additionally, I/O range from 0.68 to 0.88 percent per second and control unit utilization is almost negligible. [Ref. 21:p. II-G-3]

2. Engineering Security Systems: Physical and Software

The entire Engineering computer systems are also physically protected by a cipher lock. However, since sensitive and classified computing is done on the Vax, proper security procedures are enforced. All disks, whether floppy or hard, used on the PCs are remove from work areas and placed in a secure area. Disks that are used for sensitive or classified data gathering must be removable and lockable.

The Vax has at least two software security packages. With the Vax operating system (VMS)[12] comes built-in protection which consists of four levels. The first level is the system manager of the operating system which has overall control; the second is owner control which allows the user to give himself protection; the third is group protection; and, the fourth can allow or deny access to the world.

[11] A benchmark test is a procedure using a set of programs and files designed to evaluate the performance of the hardware and software of a computer in a given configuration. [Ref. 18:p. 42]

[12] VMS refers to a Virtual Memory Systems environment.

Their is also an alternative means of file protection offered with the VAX/VMS that is known as the Access Control List (ACL).[13] It offers a way to match the specific access you want to grant or deny to specific users. ACLs can be created for objects such as files, devices and mailboxes. Each access control list consists of one or more entries known as access control list entries. They may specify identifiers and and the access rights to be granted or denied the holders of the identifiers, default protection for directories, or security alarm details. Access control lists for each object can hold many entries which are limited only by overall space and performance considerations. The security manager maintains and modifies the ACL adding and removing identifiers as needs change. [Ref. 22:p. 17]

> ACLs enforce a security policy based on the concept of (nonexclusive) "ownership". Each segment has an access control list which gives the access modes allowed by users and group of users. The ACLs are stored in the directory containing the segment, and the directories themselves have ACLs, which are stored in the next highest directory. Because of the hierarchical nature of the storage system, users with access to high-level directories can force access to subordinate segments by altering, in turn, the ACLs of all the containing directories and that of the segment itself. [Ref. 24:p. 151]

Thus, a systems administrator with modify access to the major directory could obtain access to one of the segments belonging to other users even if the other users have written an ACL for the segment denying him access. Therefore, everyone with modify access to a containing directory "owns" a segment in the sense that they control it. The ownership of an object is critical to the outcome of a protection check using ACLs.

3. OES Security Systems: Physical and Software

According to the manager of OES, there is virtually no physical security for PCs and microcomputers unless they are in a secure area. Although access to buildings is limited, employees in the organization could easily "borrow" information even without a need-to-know. However, in a secure area such as the Think Tank, personnel are responsible for following standard procedures in the protection of classified data. As in Engineering, OES is required to remove and lock any disks which may contain classified information. If disks are fixed, they cannot be used for storage of classified information. In addition, terminal displays have to be wiped out and

[13]ACL is a list that defines the kinds of access to be granted or denied to users of an object [Ref. 23:p. 1].

computer output discarded in a proper manner.

Presently, there are no software security packages used on the PCs or microcomputers; however, NCE is aware of their need.

IV. PROCESSES WITHIN OPERATIONS

A. INTRODUCTION

Prior to documenting the requirements of a potential computer-based information system, a description of the current flow of information and the utilization of any computer systems in its operation is essential. This chapter describes the flow of information in Operations and also how automated systems are used to enhance certain aspects of information handling.

The manufacturing environment at NCE is project-oriented. The majority of contracts awarded are for the development of tactical and strategic defense systems which may require the fabrication of one or two end items. Even a production contract for this firm involving over 20,000 hours of labor may entail the manufacturing of an end item as infrequently as one every 2 to 3 months for very large systems. Because of this environment, the standard Manufacturing Information System (MIS), with its orientation toward mass production, may not be the optimum solution for the company.

In addition, because its primary customer is the federal government, some aspects of its operations must meet Cost/Schedule Control System Criteria (C/SCSC). Any recommendation for a system should recognize this fact. Consideration must also be given to modifications necessary to interface any recommended system with the C/SCSC systems already in place. This is extremely important since some of these systems are validated by the federal government for use on government contracts and must be revalidated if changes are made. This validation is absolutely essential if NCE is to be certified on future government contracts.

The information that Operations needs to perform its mission originates from a Program Office. There are 24 Program Offices located in the business directorates of NCE. These offices are responsible for evaluating Requests For Proposals (RFP) and NCE's ability to satisfy stated requirements. Should the Program Office decide to bid on a project and the fabrication/assembly of end items is required, a proposal is developed and forwarded to Operations. The proposal contains schedule criteria and engineering data (design specifications and a Summary Parts List (SPL)). Within Operations this is a two phase process.

In Phase I, Operations makes material and labor estimates and forwards them to the Program Office; Phase II occurs if NCE wins the contract and involves actual purchases of material and assembly/fabrication of end-items. If the project is a repeat of a previous order (a significant portion of Operation's business), historical data dealing with the project are used to develop the proposal. If the project involves a new system, designs are developed on a standard form called a Description of Unit Complexity (DUC) sheet. This describes how an item is fabricated and/or assembled. The Program Office forwards this information to Operations for estimates of material costs and labor costs.

B. PROJECT PROPOSALS

1. Phase I of the Project Proposal

The Program Management and Controls (PMC) office is responsible for coordinating Operations input to project proposals and for cost management of ongoing projects. This office distributes information on a given proposal to various departments within Operations for estimates of labor hours and material costs. At this point Phase I of the project proposal begins. A process diagram of Phase I is shown in Figure 4.1.

Within Operations the Material Support branch estimates the cost of the materials needed for the project. Since the majority of materials is common to many projects, most part costs can be estimated fairly accurately. Estimates on part costs are based on previous buys plus inflation factors. This provides a basis for comparison for the next step which is asking vendors for quotes. If the part is unique and there is no part history, the project office will make an engineering estimate of the cost and the materials office will ask vendors for quotes.

The Program Management and Controls department also distributes information to the functional areas that will be involved in the project. The managers of these branches distribute pertinent data to work area supervisors. Each supervisor estimates the labor hours and schedule that will be necessary in his area for the

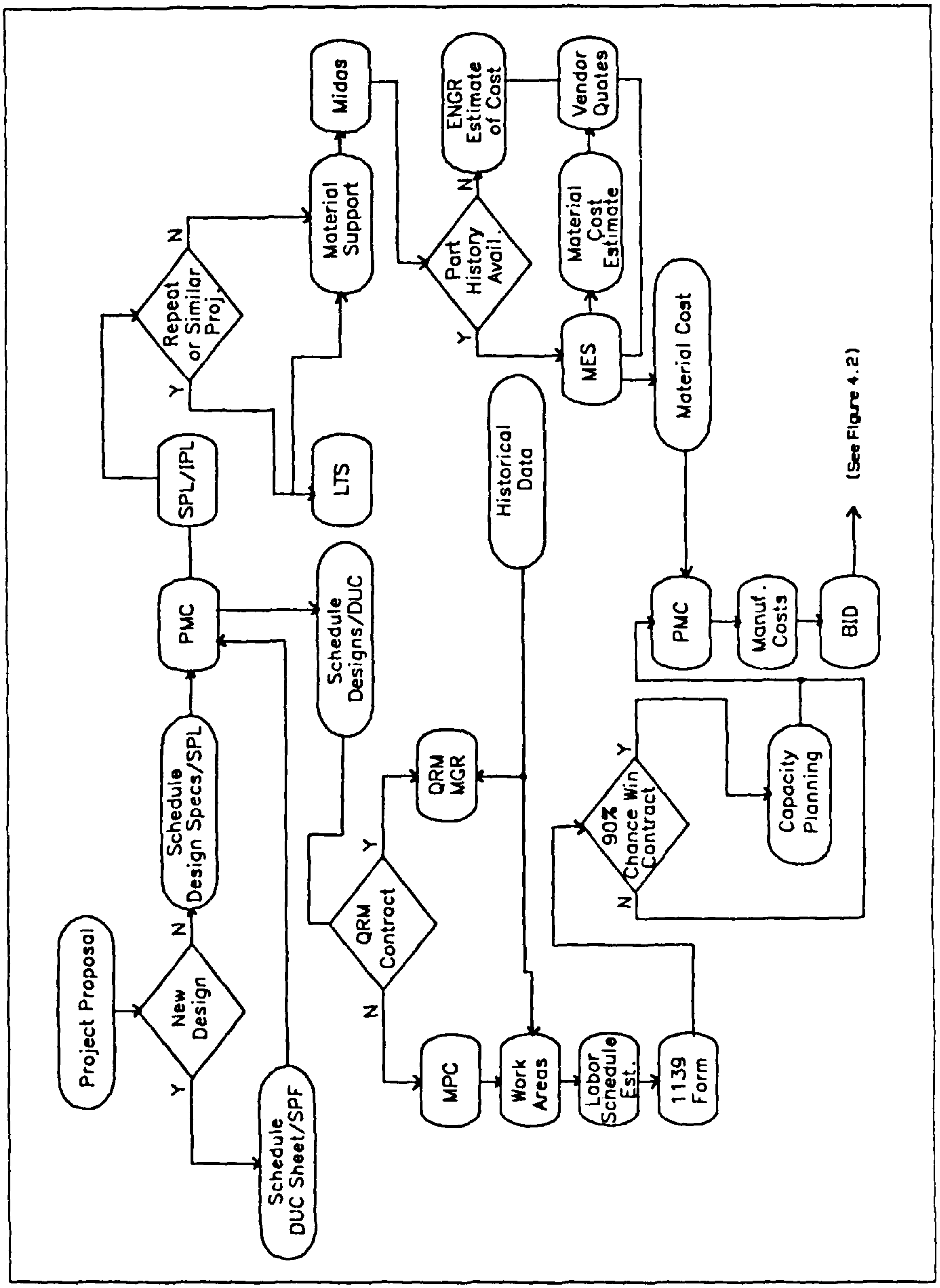

Figure 4.1 Phase I of the Project Proposal

particular project and documents these calculations on an 1139 form. These estimates are consolidated by the Program Management and Controls department and forwarded to the Program Office.

2. Phase II of the Project Proposal

If NCE wins a contract, then the Program Office notifies Operations; and, Phase II begins. Depending on the dollar value and specifications of the contract, it is handled on what NCE calls either a Prime or QRM basis. A process diagram of Phase II is shown in Figure 4.2.

Prime contracts are those that may involve a production run of an end-item and require the use of the MCS system to meet government contract accounting criteria.

Quick Reaction Manufacturing (QRM), or Walk-In Support, as it is often referred to, is oriented toward producing a prototype or a small number of a particular item. Typically, these items are manufactured to Best Commercial Practice criteria vice the MILSPEC (or more stringent) criteria required in Prime contracts. Since the majority of NCE's contracts fall under the QRM criteria, Walk-In Support is heavily used. This is due to less stringent government reporting requirements and fewer people being required in the production management process which results in lower overhead costs.

Upon notification of contract award, Operations assigns a Material Control specialist(s) to the program. This individual, or group of individuals, generate the purchase requisitions (PRs) to buy all materials. They also prepare any fabrication releases for internal fabrication and assembly requirements needed for the project. Due dates are correlated to match internal need dates in order to support the manufacturing schedule. Purchasing is responsible for ordering the material; Property Control stocks the part when it arrives; and Stores tracks parts through issuance to the floor.

The Material Control specialist notifies Stores when to issue the parts and then tracks the production process. If there are delays or problems (parts shortage or parts that do not fit), the Material Control specialists are generally the first to know and are responsible for taking corrective action or notifying those who can. Most problems are resolved at their level.

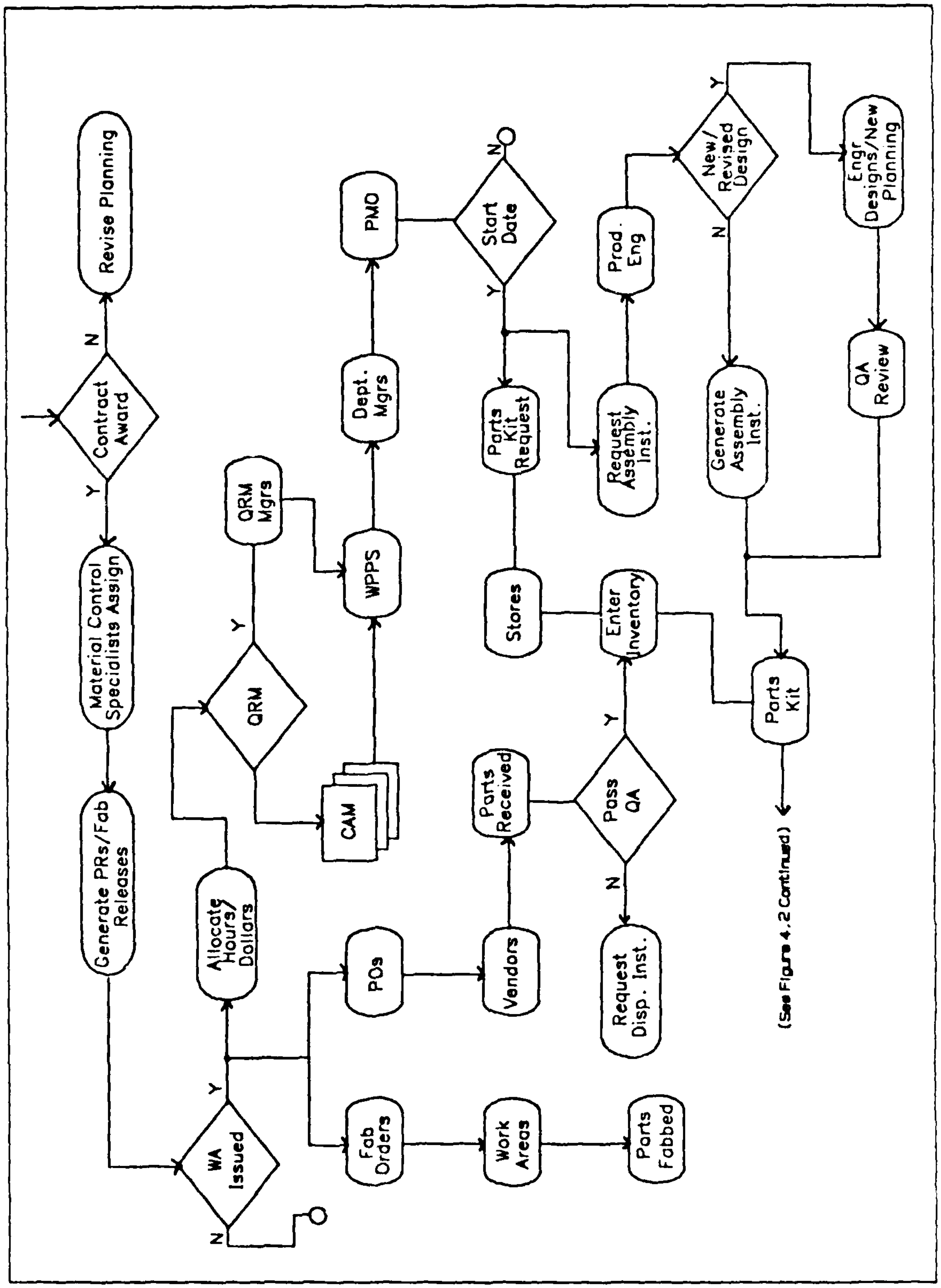

Figure 4.2 Phase II of the Project Proposal

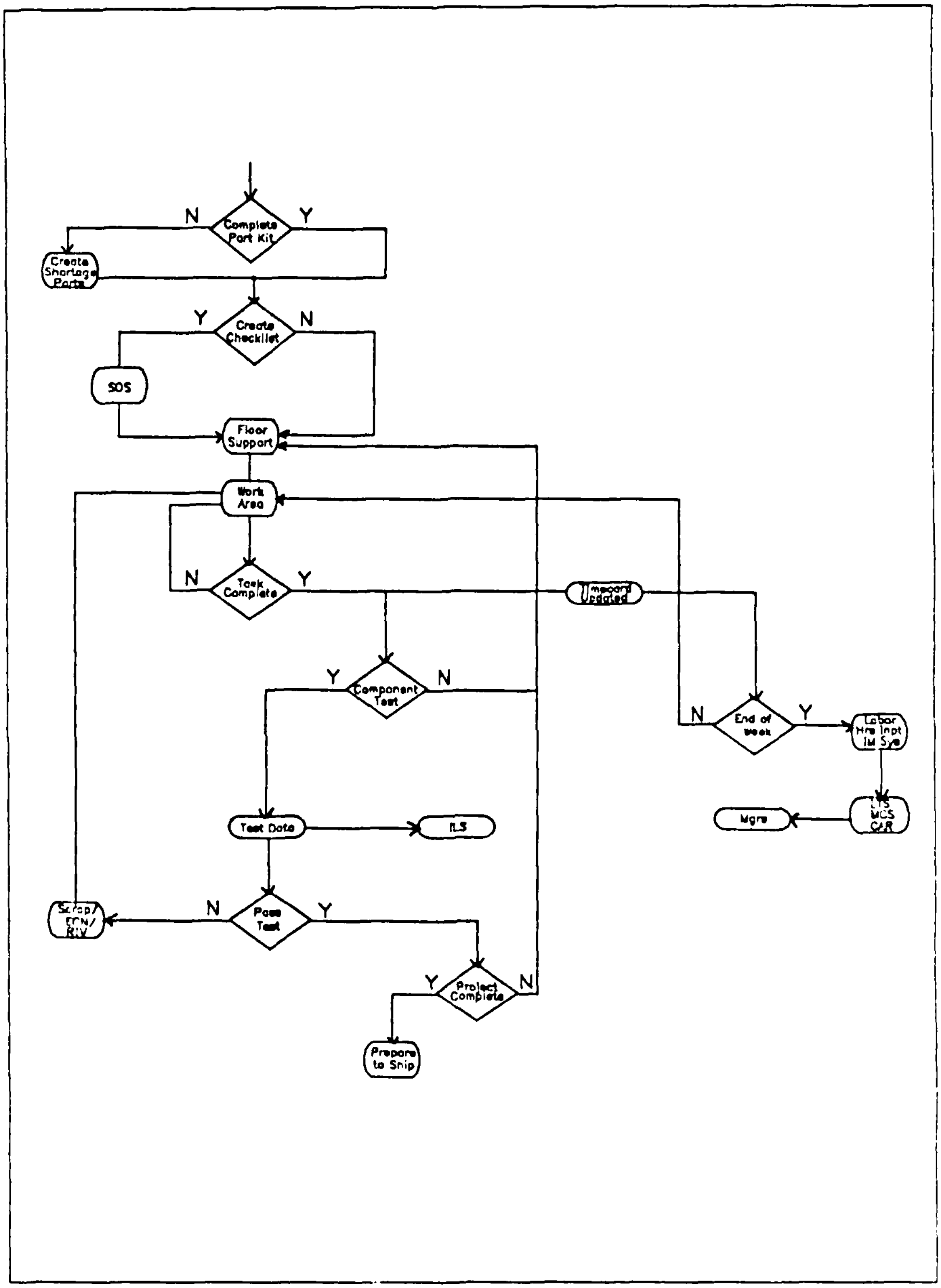

Figure 4.2 Phase II of the Project Proposal (continued)

A project task manager also plays a key role in this process. The task manager is the liaison between Operations and a particular Program Office. He is responsible for monitoring overall costs, the scheduling of tasks, and insures that the various Operations departments are supporting the program requirements as planned.

Shortly after the date of contract award, the PM distributes work authorizations to all departments involved in the program. Work authorizations define the number of labor hours and material dollars allocated to perform a specific task in a given department. For each task or group of tasks, a Cost Account Manager (CAM) is identified. This individual plans the use of his allocated labor hours and material dollars over a specific time schedule that must meet planned milestones. The calculations are made on a form called a Work Package Planning Sheet (WPPS).[14] These estimates are consolidated by department managers and forwarded to the Program Office. Work authorizations also allow the placing of purchase orders (POs) to satisfy outstanding PRs.

C. FABRICATION AND ASSEMBLY

When fabrication and assembly work is scheduled to begin, the Material Control analyst initiates a parts kitting effort within the Stores department and requests a Shop Order Form from Manufacturing Engineering. The shop order is issued; forwarded to Quality Assurance for approval; and returned to the Production shop. The Shop Order Form lists the assembly steps for the particular component and accompanies the kit. Upon notification of the material control analyst, floor support personnel pick up the parts kit from Stores and move it to the appropriate work area. As an assembly step is completed, the form is stamped with the employee ID number of the person who performed the work and the date completed.

Manufacturing Planning and Control provides floor support personnel for each shop area. These personnel are responsible for expediting the assembly fabrication process in the work area to which they are assigned. They are solely responsible for moving materials between work areas and between work stations within work areas. This is necessary in order to limit the number of people physically handling materials

[14]The WPPS displays by element of cost the time-phased budget plans for all work packages and planning packages with a cost account.

on a particular project and to facilitate the tracking of work in process. The floor support personnel are responsible for moving all materials in their work area regardless of the project.

The project analysts and CAMs track work in process through various mainframe and PC-based applications as well as manual methods. The various types of reports used by a CAM include:

- Budget report by work breakdown structure (CS1330-1 Report) contains the time-phased budget (BCWS) planned for each cost account for the entire period of contract performance and inputs for the budget report are from the detailed planning contained in the work package planning sheets.
- Monthly performance report by work breakdown structure (CS1340-1 report) presents performance measurement information for the current month, cumulative-to-date, and at-completion and also provide summary cost account performance data
- Schedule report (CS-1370-1 report) represents a listing of all task number by element of cost and performing organization within each costs account and it is used for verifying current schedule information of work authorizations and for maintaining compatibility with network-based schedules
- Performance report (LA 345-2 Report) involves work packages associated with fabrication and assembly of hardware items planned in the LTS.
- Material performance summary report (P1020-1 Report) involves the production material plan developed in MTS. Production material planning is based upon the point at which the material is kitted and issued [Ref. 25:pp. 15-17].

The CAMs have the option of entering chosen assembly steps into a computer file and updating it using the Time Share Option (TSO) available on the mainframe.

D. WALK-IN SUPPORT PROCESS

If the contract is handled on a QRM basis, much of the work in Phase I and Phase II is accomplished by one individual, the Walk-In Support Manager. All manufacturing fabrication and assembly will be requested via fabrication release issued by the material analyst to the QRM manager. The QRM manager coordinates all shop requirements, provides a manufacturing schedule, and monitors and reports on schedule and budget performance.

The QRM manager has the authority to use selected personnel from any work area required. In addition, because assembly drawings are not available (i.e. they have to work from a design), only the most experienced technicians are used for this work.

This combination of a single point of contact for cost/schedule estimates (no intermediate costs, use of experienced technicians and less stringent construction criteria (Best Commercial Practice vice MILSPEC or higher)), generally results in lower overall costs in manufacturing than is the case with Prime contracts which require more documentation to meet government requirements.

E. MONITORING OF PROJECTS

Monitoring a project as it proceeds through the manufacturing process is accomplished almost solely by comparing the actual labor hours spent on the project to the projected hours cited in the contract proposal; thus, timecards are a significant source of information. Each individual annotates his timecard on a daily basis with the charge number of any projects worked on and the amount of time spent on each project. This information, recorded manually on the timecards, is inputed on a weekly basis on several different computer systems. (It should be noted that this information is available on a weekly basis only). If more current information is desired, it must be gathered manually from several sources.

At critical phases in assembly, components are tested by the Test Engineering section. These phases occur at the conclusion of:

- Circuit Card Assembly (CCA)
- Item/Unit Assembly
- System Assembly

If the assembly passes, it is routed to the next work area; or, processed for delivery to the customer if in the system test phase. If a failure occurs, the type of error is determined; i.e., an assembly error, a design error, or a parts failure. Depending on the cause, one of a number of actions could be taken, examples are:

- Scrap
- Initiation of an Engineering Change Notice (ECN)
- Return To Vendor (RTV)

Data gathered in the test phase is forwarded to the Reliability Engineering section of the Integrated Logistics Support (ILS) Department. ILS's major objective is failure reporting, analysis, development of corrective actions, and data collection.

Manufacturing Engineering (ME) performs the role of trouble shooter in the production process. Their responsibilities include supporting new design efforts to ensure cost effective and manufacturable products, supporting the electronic assembly and metal fabrication process by implementing improved and new processes and tooling efforts; defining, meeting, and updating specifications and manufacturing instructions; improving the quality of workmanship; and resolving technical floor issues. ME supports proposal labor estimates, develops, streamlines, and controls manufacturing instructions, shop orders and other documentation. They update the Indented Parts List and the Summary Parts List (IPL/SPL) structures for manufacturing which are always unique from the design version. They must manage this data and incorporate changes on a timely basis; and, reconcile differences.

The management task in Operations can begin to be understood when it is realized that, on average, between 200 and 300 projects are ongoing at any one time. Coordination is being conducted with up to 24 Program Offices, each of which operates like an independent business. In addition, there are different accounting criteria required for handling a project as Prime, Prime without a formal government requirement, or QRM.

F. USE OF AUTOMATED SYSTEMS

Currently, NCE uses a combination of automated systems to assist in the manufacturing process. These systems represent a mixture of mainframe-based and microcomputer-based applications. In many cases, microcomputers are used to reformat data obtained from the various mainframe applications and to produce reports in a form useful to Operation's managers. In other cases, the micros are used to automate various aspects of the information flow that are critical to the smooth functioning of production processes and are not serviced by a mainframe application.

The mainframe applications present data in various ways and are largely incompatible with each other. Thus, normally, a number of applications must be accessed to gather a complete picture of a particular project. The time involved in this process sometimes makes management corrective action difficult to initiate in a timely manner.

The vast majority of proposal information on labor hours is still manually generated on 1139 forms or calculated by operations estimating programs.

When an automated system is used, it is the PEARS system. PEARS is a labor bidding system that is primarily a text processor. It has no calculating capability but does allow a Program Manager to look at a cost summary on-line. Within Operations, PEARS is used primarily by the Test Engineering branch for input to proposals concerning test bids.

The Program Offices forward information concerning a specific proposal to the Proposal Center. This information consists of design specifications and a Summary Parts List. The Proposal Center sets up the appropriate formats for proposal preparation and forwards the design specifications and SPL to Operations. Within Operations, the PMC department manually forwards the design specifications to MPC and the parts list to the Materials department.

Within the Materials department, the Material Support branch is responsible for pricing all materials in project proposals. This branch uses the Materials Estimating System (MES) to produce estimates of part costs. This system looks at previous buys of a particular item and averages the costs based on time, quantities purchased, and inflation factors. MES consists of approximately 600-700,000 records and is accessed by materiel using IBM PCs with FORTE cards.

Descriptions of parts and procurement history are obtained from MIDAS (during this phase labor history can be developed by a tie-in with LTS using SPL as a key). If the proposal involves materials not previously used by NCE, estimates of costs are obtained from the Program Office (what they think it should cost) and vendors are called by Purchasing to obtain firm quotes. As quotes are received they are input into MES.

PMC relies on the Labor Tracking System (LTS) for historical fabrication/assembly data during proposal preparation. This data is used when the proposal concerns a project that is a repeat or similar in complexity to a previous order. PMC generates data concerning cost and schedule required for previous production runs (via the previously stated tie-in with the SPL). This information along with the design specifications is forwarded to the Manufacturing department for current estimates.

Following completion of parts and labor estimates, PMC forwards the data to the Program Office. The Proposal Center then uses an application known as COSTR to take the labor hours from PEARS or 1139 and the material dollars from MES and applies labor base rates and overhead costs to price the proposal.

When NCE is awarded a contract, the material analyst must first order the required parts. This process involves the use of MIDAS. The SPL for the assemblies specified in the contract have previously been entered into this system. Parts, that are coded as purchased, have purchase requests (PRs) generated by the system. If it has been necessary to generate handwritten PRs, these must be processed through accounting, quality control, and the buying supervisor and then entered into the MIDAS data base.

Capacity planning is performed at this stage, by the manufacturing staff. They have developed a standard form on a microcomputer in which information is input manually. This information comprises a six month listing of all contracts in process and of contracts that NCE has a 90 percent (or greater) probability of winning (as estimated by the Program Office). This provides them with some idea of how much manufacturing capacity they are utilizing or may utilize and how much remains.

Master Scheduling is also being developed. Presently, its use is confined to a few projects that have relatively long production runs and therefore exhibit some stability. PMS IV is the software package being used in this effort. PCs are also being used by Manufacturing Engineering to develop automated scheduling, work center loading, and part status visibility.

When work authorizations are issued, POs are generated by MIDAS to satisfy all outstanding PRs for the project. When a part is received, the MIDAS database is updated and the part is passed to quality control which checks to insure the part meets the required specifications. The quality control phase of the parts receipt process is due to be enhanced by the implementation of the Product Assurance Data

Management System (PADMS). The first phase of this system addresses incoming inspection and planning/sampling. Phase II involves manufacturing shop floor quality assurance which includes inspection points and discrepancy reporting. If the part meets specification, it is placed into inventory; if not, the database is updated to reflect this fact and disposition instructions are initiated by the cognizant industrial engineer. The acceptance of a part into Stores is tracked on MIDAS and issuance from Stores may be tracked on MIDAS, an IN540 Form or MTS.

When work is authorized to begin on a particular project, the project analyst checks parts status on MIDAS. When sufficient parts are available and the scheduled start date arrives, the project analyst requests the kit from Stores by loading a kit list into the system. If the project is a repeat, the analyst will also request a Shop Order Form (list of assembly steps) which is available from a locally developed database known as KSOFT I. This program runs on an IBM PC AT and is operated by ME. If the project involves a new assembly procedure, operator/technicians must rely on engineering designs and new planning from Manufacturing Engineering.

Even though sufficient parts may be available to start work on a project, all parts required for completion may not have arrived. If so, the project analyst must create a shortage list. This is sometimes done in a TSO file on the IBM mainframe. The project analyst must also decide whether he wants to maintain a computer-based record of the progress on this particular project. If so, he selects which steps in the assembly process he wants to track and manually enters these into a TSO file, called SOS (Shop Order Status) on the IBM mainframe. This file does not interact with any other and is maintained at the option of the project analyst.

As the project moves through the manufacturing process, it is identified by a unique project number. At the end of a shift and/or task, each worker annotates his timecard with the charge number of the projects worked on that day and the amount of time spent on each project. At the end of the week, these timecards are sent to data entry where the information is input to the MCS, the LTS, and the CAR.

Ongoing projects are monitored using information provided by the CAR, LTS, and MCS. The CAR produces reports based on timecard input. One of the most useful reports it produces is the Weekly Detail Cost Report-Charge Number By Responsible Person (OR-100).

Reports in various formats are available from the LTS, one of which is the Weekly Labor Tracking Performance Report (LA345). This report compares actual time spent on a project to the time projected in the WPPS and produces a percentage complete figure. This capability is the closest NCE comes to automated Work-In-Process (WIP) tracking.

On a monthly basis, the Management Control System (MCS) provides information such as earned value versus planned and actuals in hours and dollars by responsible organization and WBS element (within Operations) and for Operations as a whole. Due to MCS' inability to provide this information on a more frequent basis (the system is not on-line) and a lack of complete data from any one of the weekly batch applications, various organizations within Operations track progress on a mini-MCS program that was developed within Operations.

This program is run on IBM PC's (there are more than 80 microcomputers scattered throughout Operations) owned by these organizations. The mini-MCS is known as the Program Cost Review and includes such information as: costs by departments within Operations, budgets, schedule performance tracking, estimates at completion, and schedule and cost performance for each project. Information for this program is manually extracted from the OR-100 (CAR) and the LA 345 (LTS). This method invariably results in inconsistencies between departments concerning the same project and usually results in taking time to track down the reasons for discrepancies. This also occurs when these micro outputs are compared with the MCS output at the end of the month.

Another PC generated report is the Weekly Scorecard Status. This report alerts manufacturing managers to problems with cost/schedule within a project. This report contains comments from various managers within manufacturing, elaborating on any problems.

At various stages of assembly, electronic components are tested. The test data is manually forwarded to the Reliability Engineering section of the ILS department. Approximately 300 records per week are forwarded to ILS from the CCA and Item/Unit Test sections and 40-60 records per month from the System Test section. In addition, ILS receives data via field returns which report equipment failures that occur during customer use. In ILS, the data is entered into a FORTRAN-based database known as the Failure Test database (FTS) which is resident on the IBM mainframe. ILS personnel also use SAS, a statistical package on the mainframe, in their analyses. Information is extracted as needed using TSO.

Although most of ILS' data is stored on the mainframe, approximately 75 percent of data manipulation is accomplished on PCs. A significant portion of this activity results from extracting large amounts of data from the mainframe and reducing it to pictorial representations used in meetings and reports. (ex. Information from SAS needs to be coded manually into a PC to produce graphics.)

For some large fixed-price U.S. Government contracts, the ISLIP system is used. The system begins with the initial award and tracks modifications during the life of the contract. When each end-item is ready to be shipped, the system monitors the Request for Shipment (RFS), the inspection Final Quality Assurance (FQA), and the shipment of the item.

In an effort to improve response time and access to data, the IM department's Information Center has been offering RAMIS as a solution. Various departments within Operations have been experimenting with this application including Program Management and Controls, Manufacturing Planning and Control, Material, and Integrated Logistics Support.

V. ANALYSIS OF INFORMATION FLOW AND IDENTIFICATION OF REQUIREMENT SPECIFICATIONS

A. INTRODUCTION

This chapter concentrates on the informational requirements of the Operations Organization at NCE, in particular the manufacturing functions. The methodology used to analyze the current information support is based on IBM's Business Systems Planning (BSP). BSP is a logical comprehensive top-down approach to analysis with bottom-up implemention. BSP requires the support and involvement of NCE's management and support personnel to be successful. As a result, the information gathered from our interviews may be used for planning and operational decisions.

Since data has been recognized as a corporate resource important to an organization's survival, BSP is designed to assist in the development of a system that contains consistent data to be used and shared by all users. Also, systems developed should be management and user oriented rather than data processing oriented. [Ref. 10:p. 11].

The BSP methodology has not been followed precisely due to time and distance constraints. Experienced personnel have been selected from NCE for our information gathering phase. This phase has involved the interviewing of approximately 25 people at NCE and the study of extensive documentation regarding their operation. Our observations have been compiled in draft form and forwarded to NCE for review before being finalized.

The results of any BSP analysis reflects thinking at a certain point in time and should be regarded as dynamic. A significant value of the BSP approach is that it offers the opportunity to create an environment and an initial plan of action that enables a business to react to future changes in priorities and direction without radical disruptions in systems design and define an information system function to continue the planning process.

Our use of the BSP methodology is not intended to serve as an analysis of the Operations organization. Rather, our use of BSP focuses on the analysis of information systems support to the manufacturing function within Operations. At this level our intent is to develop general trends concerning current systems support and the potential utility of a single database system.

The premise for conducting a BSP study is that there exists within the NCE organization a need for significantly improved computer-based information systems (I S). The BSP methodology concept involves how these information systems should be structured, integrated and implemented. The basic concepts of BSP can be related to the long-term objectives for I S in an organization. If an I S system is to be effective and efficient, the following must be considered:

- An I S must support the goals and objectives of the business
- An I S strategy should address the needs of all levels of management within the business
- An I S should provide consistency of information throughout the organization
- An I S should be able to survive through organizational and management change
- The I S strategy should be implemented project by project to support the total information architecture [Ref. 10:p. 5].

Our modified BSP methodology consists of four essential steps with the use of matrices as our primary analysis tool. They are identification and definition of business processes; identification and definition of data classes; data flow determination; and current systems support.

B. IDENTIFICATION AND DEFINITION OF BUSINESS PROCESSES.

The first step of our modified BSP methodology is the identification and definition of business processes. Business processes are those activities performed in a business that are essential to its viability and do not change with management or reorganization.

To identify NCE's processes, we used the description of the manufacturing workflow provided in Chapter IV. The flow diagram shown in Figures 4.1 and 4.2, that accompanies the description, is the starting point for identifying the processes that are important to the manufacturing operation. Additional data has been gathered from documents concerning manufacturing strategy, IM plans, and plans and studies of manufacturing and its requirements conducted over the past few years. The correct identification of these processes is important since they form the basis of virtually everything that follows in the next three steps.

As a result of our study of these sources, we have identified 33 processes which are important to the operation of the manufacturing function at NCE. These processes and a description of each is provided in the next section.

C. NCE BUSINESS PROCESSES AND DEFINITIONS

The ***Distribute Design Specifications and Bill of Materials (BOM)*** process distributes the engineering design specifications and an Indented Parts List (IPL) to those manufacturing departments that are involved in the project covered by the proposal. This activity also involves the distribution of a Summary Parts List (SPL) to the Materials department for use in development of material costs.

The ***Schedule Production*** activity develops the information needed by management to analyze and evaluate the manufacturing resource requirements of current and planned programs.

The ***Estimate Labor Hours*** activity estimates the direct labor hours necessary to accomplish the work as described by engineering designs and an IPL.

The ***Plan Capacity*** activity develops the information needed by manufacturing regarding available resources and capacity constraints at the work center level over a 26 week period.

Develop Material Costs process establishes costs of raw materials as described in the SPL.

Consolidate Hours/Costs process is the collection of input from all departments involved in a potential project concerning required direct labor hours and material costs.

The ***Workflow/Balancing/Facilities Layout*** process includes the following activities:

- Workflow is planning the sequence of operations or other activities and the movements of materials, parts, supplies and documents
- Balancing is providing the proper number of similar, or dissimilar, work stations or equipment to produce the appropriate mix of finished products
- Facilities layout is the location of equipment, storage areas, and service areas in the facilities.

The ***Generate Material Requests*** process creates purchase requests for material needed for a particular program that must be procured from outside sources. This activity also includes the creation of fabrication releases for the production of some sub-assemblies which will be accomplished in-house.

The ***Determine Material Need Dates*** process involves the development, for a given program, of the material need dates and quantities for all of the detail material necessary to support the program requirements as indicated by contract requirements and manufacturing resource availability.

The ***Purchase Materials*** process involves the issuance of purchase orders to vendors for the procurement of all materials needed from outside sources for the completion of product assembly.

The ***Plan Task Execution*** process involves the planning, by work center, for the accomplishment of a specific task, over a specific time period, given a specific budget as defined by a work authorization.

The ***Receive Materials*** activity receives materials, checks them against outstanding PO's PR's and establishes accountability.

Inspect Materials is a process which involves the inspection of materials to ensure they meet required specifications.

The ***Control Materials*** activity include the storage, securing, and accounting for raw materials prior to issue to the shop floor.

Request Parts Kitting is the activity of requesting the Stores department to assemble specified parts as defined by a parts list provided by a material specialist.

Request Assembly Instructions is the process of requesting a generation of instructions for the assembly of a given set of parts. This assumes the product has been produced on-site before. If the product is new or has been modified, engineering designs are studied and new planning is necessary.

The ***Assemble Parts Kit*** process involves the location and collection of a specified set of parts into a kit.

The ***Generate Assembly Instructions*** process involves the creation of instruction for guiding the assembly of a specific component.

Approve Assembly Instructions activity includes the approval, by Quality Assurance, of assembly instructions for components which have not been produced on-site before or on instructions which have undergone revision.

Generate Shortage List activity includes the creation of a list which contains data about parts which are needed for the completion of a project but which have not been received by the start of the assembly process.

The ***Create Assembly Milestone List*** involes the generation of a list containing selected steps in the assembly process which may be used to measure progress in the production phase.

The ***Manufacture Product*** process is the actual production of finished products.

The ***Test Component*** process is the function of testing a component/sub-assembly to ensure it meets required specifications.

The ***Forward Test Data*** is the activity of collecting test results from all testing sites and sending it to the appropriate organization.

Track Product Performance process includes tracking and measuring the performance of a product from testing through field use, together with failure rates.

The ***Submit Hours*** process involves the reporting of direct labor hours expended on each project task.

The ***Track Work-In-Process (WIP)*** activity controls the flow and balance of work-in-process within prescribed limits and monitors the status of each program.

The ***Monitor Product/Process Specifications*** activity includes Maintenance of records regarding product definition and the incorporation of engineering changes.

The *Cost Management* activity includes the monitoring of material and labor costs for each project in manufacturing and the corrective action taken if necessary.

Determine Methods and Standards activities establishes the proper work station, motion pattern, and equipment used on operations. It also sets the correct time to perform the operation using an established method for purposes of work measurement and/or costing.

The *Product Quality Control* process includes the functions of inspecting, controlling, and reporting on the quality of finished products.

The *Measure Performance* process provides feedback information on actual production against program requirements on a periodic basis. It also provides input for any required modification of plans and schedules.

The *Manage Operations* activity includes producing products or parts according to assorted program schedules and specifications in the most efficient manner; determination of status of each program on an as-needed basis and the corrective action taken if necessary. In addition, it includes planning of material, manpower, and optimum use of equipment.

D. THE PROCESS/ORGANIZATION MATRIX

To relate the business processes to the organizational structure of the NCE, a Process/Organization matrix shown in Figure 5.1 has been developed which displays the primary organizations involved in the manufacturing process. Essentially, this is a graphic representation of one aspect of the management system of the organization because it illustrates who makes the decision in each of the processes.

Since the BSP study is intended to provide a broad overview of the business, not every organizational unit is identified. Furthermore, common similar organizations may be represented as one unit; in our matrix the Metal Fabrication and Assembly shops have been combined under the designation 'Work Areas'.

The Process/Organization matrix is a representation of the routine processes that occur at NCE on a daily basis. Further, it shows the extent to which organizations have responsibility for decision making in the processes. Major responsibility and decision maker involvement is indicated by an 'X' with a dot in the

PROCESS / ORGANIZATION	Distribute Design Specs/BOM	Schedule Production	Estimate Labor Hours	Plan Capacity	Develop Material Costs	Consolidate Hours/Costs	Deter. Wkflow/Balancing/Fac Layout	Generate Material Requests	Determine Material Need Dates	Purchase Materials	Plan Task Execution	Receive Materials	Inspect Materials	Control Materials	Request Parts Kitting	Request Assembly Instructions	Assemble Parts Kit
Program Office	X	/			/	/		/	/	/	X				/		
Proposal Center	/		/		/	X											
Prog. Mgmt. & Control	**X**		/		/	**X**				/	/						
Materials	/	/			X		/	X	X	/	/	X	/	/	/		/
Materials Support					**X**					/			/				
Purchasing									/	**X**			/				
Property Control												X	/	**X**	/		X
Stores														X	X		**X**
Manufacturing	/	X	/	/		/	X	/	/		/				/	/	
Walk-in Support		X	**X**	X			/	/	/		**X**				/	/	
Manuf. Planning & Control		**X**	/	**X**			X	**X**	**X**	X	X				**X**	**X**	
Test Engineering			X	/			/				/						
Production Engineering		X	/	X			**X**		/		/				/	X	
Work Areas		/	**X**	/			/		/		**X**				/		
Integrated Log. Support																	
Quality Assurance													**X**				

PROCESS / ORGANIZATION	Generate Assembly Instructions	Approve Assembly Instructions	Generate Shortage List	Create Assembly Milestones	Manufacture Product	Test Component	Forward Test Data	Submit Hours	Track Work-in-Process	Monitor Product/Process Specs	Cost Management	Determine Methods & Standards	Product Quality Control	Measure Performance	Control Manufacturing	Track Product Performance
Program Office	/	/		/	/	/				X	X		/	/	/	X
Proposal Center											/					
Prog. Mgmt. & Control				/							**X**			**X**	/	
Materials			/						/		/	/	/	/	/	/
Materials Support																
Purchasing			/								/					
Property Control			/						/							
Stores			X													
Manufacturing			/	/	X	/			X	/	X	/	/	X	**X**	/
Walk-in Support		/	/	/	X	/			X	X	X	/	/	X	/	/
Manuf. Planning & Control		/	**X**	**X**	X	/			**X**	/	X	X	/	X	X	/
Test Engineering					/	**X**	**X**		/		/	/	/	/		/
Production Engineering	**X**	/		/	X	/			X	**X**	/	**X**	/	/	X	/
Work Areas				X	**X**	/		**X**	X	/	X	X	/	X	/	/
Integrated Log. Support						/	X			X		X	/	/		X
Quality Assurance	/	**X**			/	/				/			**X**	/		/

KEY:

X Major Responsibility & Decision Maker

X Major Involvement in the Process

/ Some Involvement in the Process

Figure 5.1 Process/Organization Matrix

middle; major involvement in the process is indicated by an 'X'; and, some involvement in the process is indicated by a '/'. These notations make the interpretation of the matrix output relatively straightforward. That is, by looking at each process column, the amount of organizational interface can be determined.

However, these definitions only signify the levels of decision making within the organization and are not meant to describe the actual responsibility of each of the organizational units. They are intended to serve only as a guide to assigned responsibility for and involvement in a process.

In the Process/Organizational matrix the major decision makers are identified for specific activities. For example, the Manufacturing Planning and Control organization is a major decision maker involved in several processes. These include schedule production, estimate labor hours, plan capacity, generate material requests, determine material need dates, request parts kitting, request assembly instructions, generate shortage lists, create assembly milestones, and track IP. However, it must be kept in mind that all processes involve the General Manager (GM) of NCE as the head decision maker.

Because there are a large number of processes to manage, delegation of control becomes an important priority from the GM office to the PM office and down through the several layers of organizational structure. Since some processes such as production standards require certain governmental control criteria, the GM's involvement in every day decisions is not necessarily required.

The purpose of this output is to gain an understanding of how the NCE organization operates and how it is managed and controlled. The ultimate use of the business processes is to identify opportunities and requirements for the use of information systems to support the business.

E. IDENTIFICATION AND DEFINITION OF DATA CLASSES

The second step of our analysis involves the identification of things that are significant to the business. These things (entities) are the output of the business processes defined in the first step. Data classes which are a logical grouping of data related to entities that are significant to the organization are also identified. It is necessary to identify what data must be available and what data is created for business activities and decision making. We have accomplished this with the completion of a Data Usage Analysis Sheet which displays for each process the types of data used to perform the process under the heading 'Data Required'; the process itself under the heading 'Process'; and, the types of data that the process creates or generates under the heading 'Data Created" [Ref. 10:p. 37]. Items listed under "DATA REQUIRED" are not intended to represent all data used in the process but to serve as an example of the more significant data required by the process. This information is shown in Table 5.

TABLE 5

DATA USAGE ANALYSIS

DATA REQUIRED	PROCESS	DATA CREATED
Eng. Design Summary Parts List Delivery Dates Tasks Involved	Distribute Design Specs and SPL	Proposal Package
Future Production Req. Proposal Production Req. Ongoing Production Req. Current Production Capacity	Schedule Production	Master Schedule
Eng. Design Labor History(if any) Proj. Start/Finish Dates	Estimate Labor Hours	Project Labor Hours
Project Schedules Current Projects Planned Projects Labor Availability Equipment Availability	Plan Capacity	Manufacturing Capacity
Parts List Parts History Vendor Quotes Quality Specs	Develop Material Costs	Project Material Costs
Labor Hours Material Costs Program No.	Consolidate Hours/Costs	Project Manufacturing Requirements
Labor Hours Material Costs Overhead Rates Base Rates Projected Costs	Cost Management	Cost Reports
Proj. No. SPL Due Dates	Generate Material Requests	PR's/Fab Releases
Proj. No. Start Dates Due Dates Lead Times	Determine Material Need Dates	Materials Due Date
Work Authorization PRs Fab Releases	Purchase Materials	POs/Fab Orders
Labor Hours Material Dollars Schedule CAM Task	Plan Task Execution	Work Package/ Planning Package

TABLE 5

DATA USAGE ANALYSIS (CONT'D.)

DATA REQUIRED	*PROCESS*	*DATA CREATED*
Parts Specs POs Proj. No.	Receive Materials	Material Receipt
Specifications Vendor	Inspect Materials	Material Standards
Part No. Proj. No. No On-Hand Location Access Authorization	Control Materials	Inventory Locations
Proj. No. Tasks Parts List Request Date	Request Assembly Inst.	Shop Order Request
Proj. No. Parts List Parts Shop Order Form	Assemble Parts Kit	Parts Kit
Proj. No. Available Parts Required Parts	Generate Shortage List	Shortage List
Shop Order Form Revision Quality Assurance	Approve Assembly Inst.	Revised Assembly Inst.
Shop Order Form Milestones Due Date	Create Assembly Milestones	Shop Order Status
Parts List Proj. No. Product History	Generate Assembly Inst.	Shop Order
Parts Kit Labor Equipment	Manufacture Product	Product
Project Number Performance Specs Design Specs	Test Component	Test Data
Project Number Component Type Test Date	Forward Test Data	Test Database

TABLE 5

DATA USAGE ANALYSIS (CONT'D.)

DATA REQUIRED	*PROCESS*	*DATA CREATED*
Employee ID Work Area Charge Number Hours	Submit Hours	Direct Labor Hours
Project Number Project Workflow Due Dates Location of Material Status of Assembly	Track Work-In-Process	Project Status
Project Number Planned Hours Actual Hours Planned Material Actual Materials Planned Schedule Actual Schedule	Measure Performance	Performance Evaluation
Project Number Performance Evaluation Project Status Priorities	Control Operations	Action Messages
Standards Specifications	Product Quality Control	Product Standards
Customer Feedback Repair Reports Spare Parts	Track Product Performance	Reliability Info
Tasks Resources Priorities Desired Results	Determine Workflow/ Balancing/ Facility Layout	Production Processes
Historical Data Task Standards	Determine Method and Standards	Time Standards
Tasks Specifications	Monitor Product/ Process Specification	ECN,EHO,etc.

After studying the Data Usage Analysis, we have identified 36 data classes which are important to the operation of the manufacturing function at NCE. These data classes and a description of each is provided in the next section.

F. NCE DATA CLASSES AND DEFINITIONS

The ***Engineering Design Specifications*** data class involves product definition and assembly.

The ***Bill of Materials (BOM)*** data class describes the components of the product, including raw material and the sequence of steps in product fabrication.

The ***Schedule Requirements*** data class involves contractual requirements for delivery of end items.

Estimated Manufacturing Requirements data class are the consolidated results of the estimation process within the manufacturing and material departments and represent the cost and hours to manufacture the items specified in a given proposal.

Cost Reports data class are the labor and material cost reports for each project being worked on in manufacturing.

Master Schedule is the data class which shows the current demand on manpower and plant capacity by function and program. (Currently accomplished for a few programs that exhibit some stability.)

The ***Capacity Plan*** data class balances manufacturing resource demands against manufacturing resource capabilities.

Purchase Requests/Fabrication Releases are documents which establish the need for acquiring material from external sources (PR's) and the requirement for fabricating a specified sub-assembly in-house.

Material Due Dates are the dates by which externally acquired material must be available if the manufacturing process is to meet its schedule for a given program.

The ***Parts List*** data class is a list of parts which are required to assemble a specified component.

The ***Shop Order Request*** data class is a request for issuance of assembly instructions for a specified set of parts for a specified component.

A ***Shortage List*** data class is a list of parts not available in inventory at the time of issuance of a parts kit.

A ***Shop Order Status*** data class is a list of assembly steps selected to track the progress of the manufacturing effort on a particular component.

Program Status is a data class indicating the status of each program currently in the manufacturing environment, in terms of labor hours and materials expended.

The ***Estimated Material Costs*** data class is the material costs required for a specified program.

The ***Purchase Orders*** **of** data class is data concerning a business order for goods from a supplier.

The ***Material Receipt*** data class is data related to the receipt of vendor shipments.

Inventory data class contains data on the location, quantity, and cost of raw materials.

Parts Kit data class is data on the parts that are required to assemble a specified component.

Revised Assembly Instructions data class contains assembly instructions that reflect engineering design changes and are approved by Quality Assurance personnel.

The ***Material Description*** data class describes all the construction and performance criteria that specified raw material must meet.

Product Standards is data that describes the construction and performance standards that the finished product must meet.

The ***Estimated Labor Hours*** data class contains direct labor hours estimated as necessary to produce a specified component end item.

Work Package/Planning Package is a plan that describes how allocated labor hours and material dollars will be used to meet a specific schedule.

The ***Product*** data class describes all basic attributes of the product including identification, classification, pricing, and quality information.

The ***Actual Labor Hours*** are the hours expended in construction of a particular component or end item.

Actual Material Costs is the cost of material actually used to construct a product.

Test Data is the data class that describes the performance of a particular component compared to some specific criteria.

Test Database is a collection of test data.

Reliability Information is a data class which describes the failure rates of components or end items.

Production Processes is a data class which describes a sequence of operations or other activities and the movement of materials, parts, supplies and documents; a number of similar or dissimilar work stations or equipment; and the location of equipment, storage areas, and service areas in facilities.

Time Standards

is the data class concerning standard times to perform specified operations in a certain manner.

ECN, EHO, etc. is a data class which describes alterations in engineering designs for specified products.

Shop Orders contain data describing the assembly steps necessary to produce a specified part.

Performance Evaluation is the data class describing the performance of manufacturing organizations measured against various criteria.

Action Messages data class contains data concerning measures taken to optimize the performance of all manufacturing elements in the use of manpower, material, and equipment.

G. THE PROCESS/DATA CLASS MATRIX

To relate the business process to these data classes, a Process/Data Class matrix has been developed and is shown in Figure 5.2. The processes are listed down the vertical axis and the data classes across the horizontal axis. Looking at the Data Class/Process matrix we can determine which data classes are associated with what processes as well as when the data is created, used, or not used.

These relationship are one of three types. The first relation type is creation (C); i.e. when the process creates a data class. Starting with the first process each data class that is created by a process has a 'C' placed at the intersection of the appropriate row and column. This is accomplished for all processes and data classes. The 'C' designation is important since it means that the identified process is the best source for ensuring the integrity of the data class. For example, a Schedule Production process is created by a Master Schedule data class; or, a Distribute Design Specs/BOM process is created by Engineering Design Specs, BOM, and Schedule Request data classes.

The second relation type is usage (U), in which the process uses the data class. Following the assignment of Cs each process row is examined again and the 'U' is placed in the column of each data class used by that process. For example, Determine Material Needs Dates process uses Engineering Design Specs, BOM and Schedule Request data classes even though they are created by a different process.

The third relation is no involvement which is indicated by a blank. That is, the Cost Management process does not use data obtained from Engineering Design Specs, BOM or Schedule Request.

The relationship of processes to data classes for all activities can be determined by examining the matrix. Once all the relationships have been labelled, the Process/Data Class matrix is re-examined and regrouped.

The regrouping of processes and data classes begins the third step of our information analysis of data flow determination. The regrouping of processes and data classes is accomplished by listing the planning and management control processes first followed by the remaining processes.

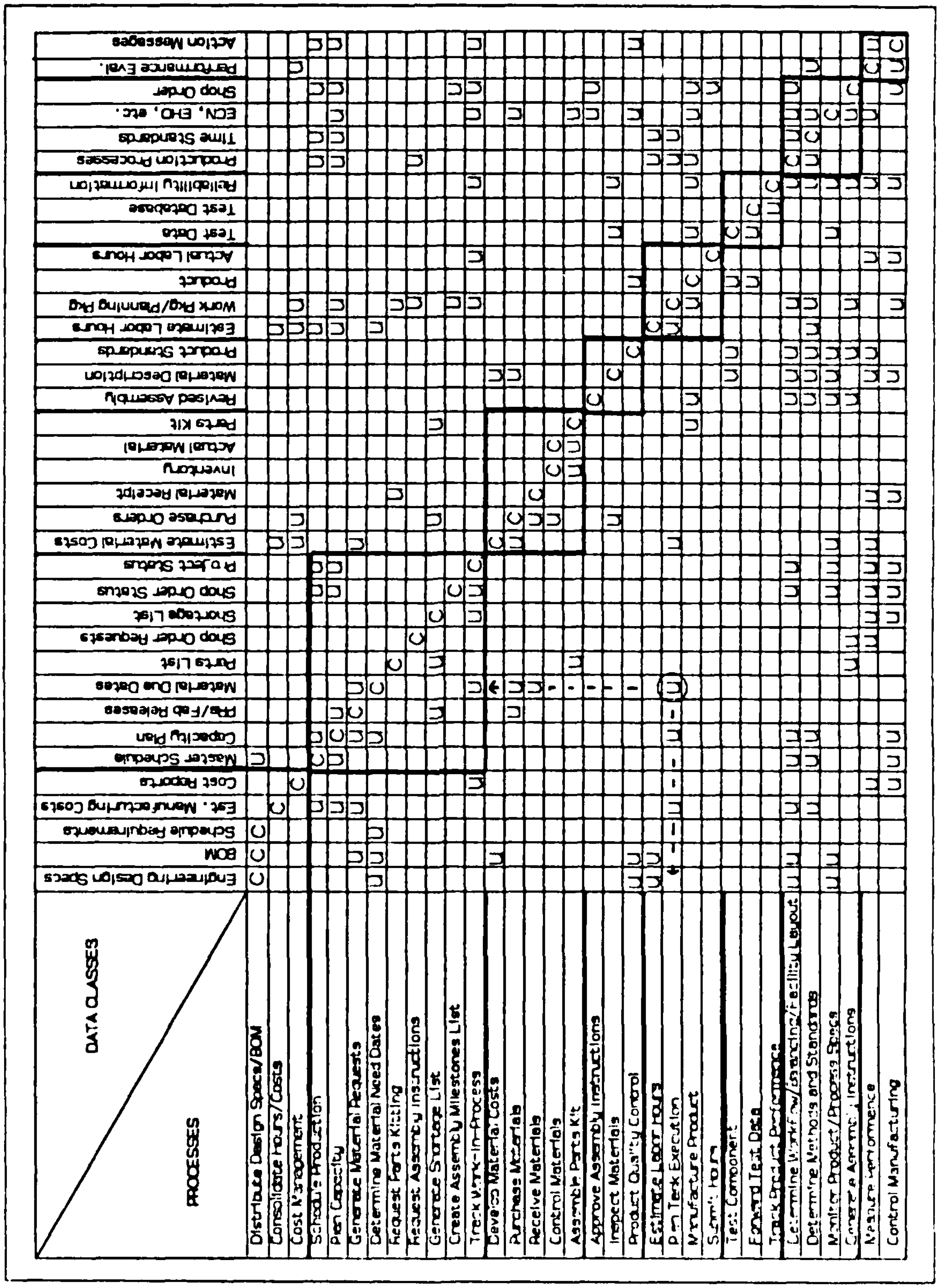

Figure 5.2 Process/Data Class Matrix

By moving data class columns so that the groupings of C's and U's start at the upper left and move to the lower right, processes and data groups are identified. For example, the data classes Estimate Material Costs, Purchase Orders, Material Receipt, Inventory, Actual Material Costs and Parts Kit should remain under the control of the Materials department since they create and use these records. Sometimes, however, when several departments use the same data, it is more difficult to determine which department should have control of the data. But, usually the activity that creates the data should probably also control it.

This restructuring clearly shows system modularity as identified in Figure 5.2 with the use of superimposed blocks. The rearranging of the axes of the process and data classes can be related to organization personnel and structure. That is, data elements can be grouped into proper parts of the organization. This arrangement of process and data classes causes the 'C's' in the matrix to appear along the diagonal.

The Process/Data Class matrix also identifies the data flow determination between process groups. Whenever data is used by a process and that data is created by a process in another grouping, an arrow has been drawn from the creating groups to the using group. For example, the Material Due Dates data class is used by the Plan Task Execution process, but it is created by Determine Material Need Dates process. This relationship is illustrated with an arrow drawn to show the flow of information from the process group of which Material Due Dates belongs to the process group to which Plan Task Execution belongs. The need for data flow is represented by all 'U's' outside of group boundaries.

The result of this data flow is an Information Architecture Flow Diagram described in the next section.

H. INFORMATION ARCHITECTURE FLOW DIAGRAM

From the Process/Data Class matrix, an Information Architecture Flow Diagram has been constructed and is shown in Figure 5.3. It illustrates the information architecture and enables the evaluation of data sharing within NCE. The diagram simplifies the overall picture of required information flow in the NCE organization by grouping closely related processes and data classes and indicating how data flows between them.

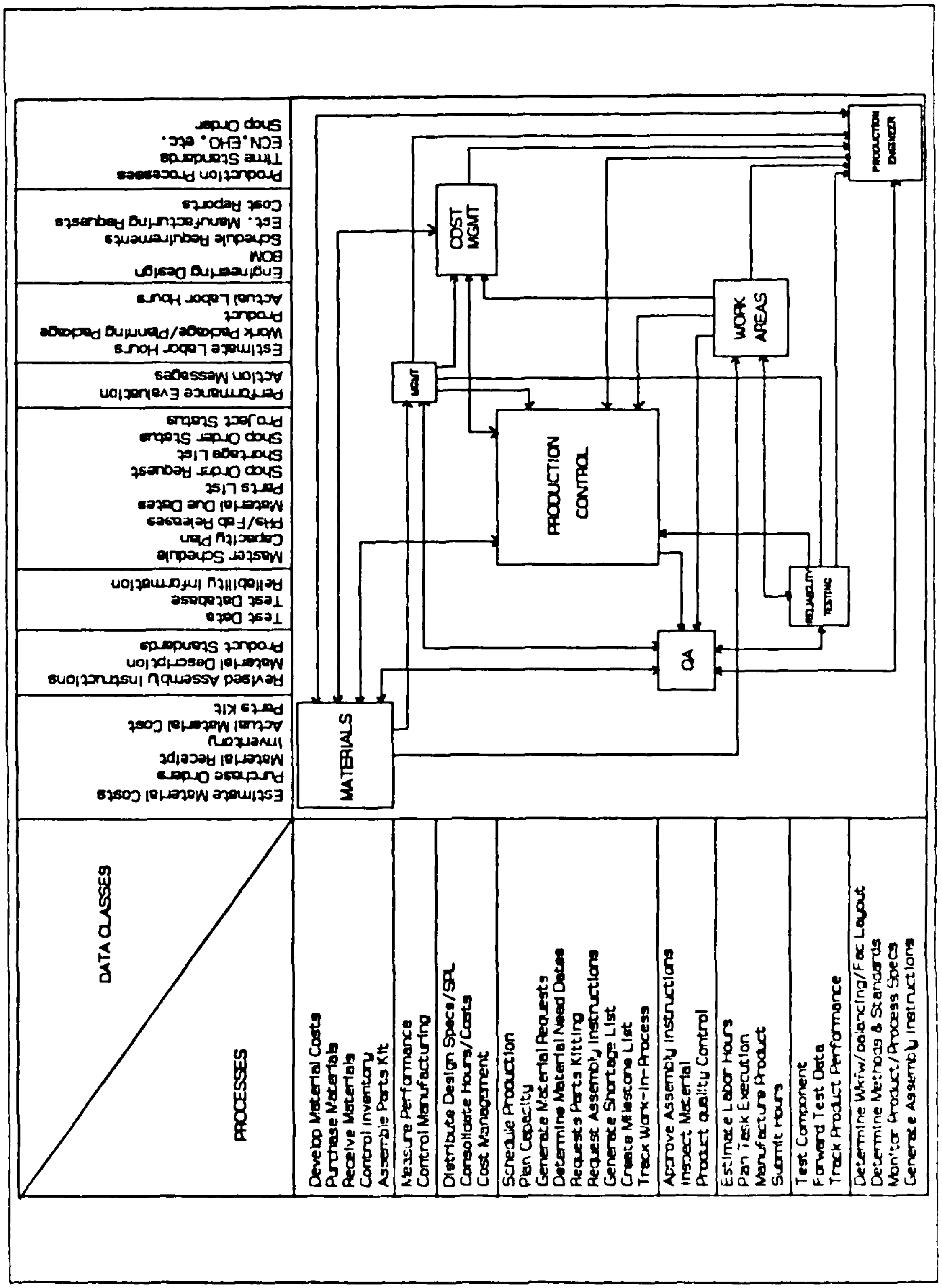

Figure 5.3 Information Architecture Flow Diagram

This architecture drawing can be useful because it provides some recommendations for long-range information systems implementation and also provides a foundation for follow-on resources and tactical planning.

The diagram identifies, with the use of boxes, the information systems that form the long-range plan. Reading vertically, the matrix displays data controlled by each information system; reading horizontally, the matrix displays the business processes supported by each information system; and, finally, it shows the flow of information between the various information systems and then shows the flow of information through the business itself.

From this information, the feasibility of computerization of a subsystem or group of processes may be established. Since most of these processes occur within the various departments of the Operations organization, they have certain commonalities which may provide the basis for computerization.

The output of this matrix clearly indicates that a centralized database which includes materials, quality assurance, production control, management, program management and control, work area processes, and production engineer subsystems would be beneficial to NCE. Information from each of these modules needs to be shared by nearly all the other modules. This sharing can easily be accomplished through an interactive operating system environment as an initial step toward an information manufacturing system. Of course, certain security controls would have to be in place to maintain data integrity and control.

Since input information to the materials, production control, and reliability testing, is extensive and important to NCE's survival, development and implementation of these modules should probably take priority. Also, the production control and material subsystems create and use several of the key business processes and data classes which are crucial to manufacturing. In addition, NCE's critical success factors of cost, schedule and quality could be more easily obtained.

While time has not allow us to extend this analysis outside of the manufacturing environment, there are still some relatively obvious links that this architecture could use to enhance its utility. An obvious one is the link between the materials module and the financial functions of NCE to record obligations as they are incurred through the issuance of purchase orders. Another channel of information that would be very useful would link the production engineering, reliability testing, and quality assurance modules with the engineering organizations. This would enhance the timeliness and accessibility of such information as engineering design changes, project start, stop and hold information; the transmission and revision of work authorizations, planning packages, and other data that manufacturing needs to operate efficiently.

The data on this matrix has been developed from our interpretation of information received from NCE. A key aspect of BSP is the management interviews which serve to validate and refine the processes and data classes chosen for our initial matrix model as well as written documentation given to us by the organization.

I. ANALYSIS OF CURRENT SYSTEMS SUPPORT

The final step in our modified BSP study is analyzing current systems support. In order to develop recommendations for future actions, it is necessary to understand how data processing currently supports the organization. This is accomplished through the use of two more matrices. However, these matrices cannot indicate present problems, the extent of support needed, or the value of this support to each of the processes. This type of information has been identified through interviews and the examination of material obtained from NCE.

1. The System/Process Matrix

To obtain an overall view of existing and planned data processing support, a System/Process matrix has been created and is shown in Figure 5.4. This matrix identifies which processes are receiving systems support. It also identifies processes receiving no current systems support; processes receiving systems support in some organizational units but not all; and potentially redundant systems.

The 'C' in the Systems/Process matrix, indicates which processes are currently receiving systems support; the 'P' indicates which processes have been planned to receive systems support; the 'C/P' indicates current and planned support for processes: a blank indicates no current systems support. It displays how systems support the business environment in order to develop recommendations for future action and helps management to determine requirements for information support.

SYSTEM \ PROCESS	Distribute Design Specs/SPL	Consolidate Hours/Costs	Cost Management	Schedule Production	Plan Capacity	Generate PRs/Fab Releases	Determine Material Need Dates	Request Parts Kitting	Request Assembly Instructions	Generate Shortage List	Create Assembly Milestones	Track Work-In-Process	Develop Material Costs	Purchase Materials	Receive Materials	Control Materials	Assemble Parts Kit
Proposal Preparation		C^3											C^1				
Master Scheduling				C^1_3													
Capacity Planning					C^3												
Material Tracking			C^1									C^1	C^1			C^1	
Material Information			C^1			C^1	C^1	C^1						C^1	C^1	C^1	C^1
Material Estimating			C^1										C^1				
Labor Tracking			C^1									C^1					
Shop Order Status											C	C^1					
Shop Order Generation									C^3			C^3					
Component Testing																	
Reliability Engineering																	
Product Assurance																	
Part Status																C^3	
Cost Accounting			C^1									C^1					
Management Control			C^1		C^1		C^1					C^1				C^1	
Program Cost Review			C^3									C^3					
Weekly Scorecard Status																	

SYSTEM \ PROCESS	Approve Assembly Instructions	Inspect Material	Product Quality Control	Estimate Labor Hours	Plan Task Execution	Manufacture Product	Submit Hours	Test Component	Forward Test Data	Track Product Performance	Deter. Wkflow/Balancing/Fac Layout	Determine Methods & Standards	Generate Assembly Instructions	Monitor Product/Process Specs	Measure Performance	Control Manufacturing
Proposal Preparation				C^3				C^1								
Master Scheduling																C_3
Capacity Planning					C^3							C^3				C^3
Material Tracking															C^1	
Material Information		C^1													C^1	
Material Estimating																
Labor Tracking				C^1								C^1			C^1	
Shop Order Status															C^1	
Shop Order Generation																
Component Testing								C^3								
Reliability Engineering										C^1_2		C^3		C^2		
Product Assurance		C^1						$^{3}/_{P1}$								
Part Status																
Cost Accounting															C^1	
Management Control														C^1	C^1	C^1
Program Cost Review															C^3	
Weekly Scorecard Status															C^3	C^3

KEY:

C = Current

P = Planned

C/P = Planned

Systems:

1 IBM

2 VAX

3 PC-based

Figure 5.4 System Process Matrix

The available systems are either the IBM mainframe whose use is indicated by a 1 on the matrix; the Vax mainframe whose use is indicated by a 2 on the matrix; and, PC-based systems whose use is indicated by a 3 on the matrix.

Unfortunately, the Process/System matrix does not display how or to what extent interaction is needed among processes and systems; nor does it show networking between the various systems. It does, however, describe information interaction among processes and systems. For example, the Cost Management process is currently using Material information, tracking estimating and labor systems from the IBM mainframe and is also using the Program Cost Review System which is PC- based.

2. The Systems/Data Class Matrix

The Systems/Data Class matrix which is shown in Figure 5.5 displays what portion of the data classes at NCE is currently automated and which systems use what data.

The available system applications form the vertical axis while the data classes, grouped by similarity, form the horizontal axis. An X is placed in each appropriate box to show which data classes support which systems.

From the Systems/Data Class matrix, all of the data is shown that is shared among and between various systems. In particular, the BOM, Engineering Design Specification, Estimated Materials Cost and Product Data Classes need a significant amount of information from many of the same systems. This re-emphasizes the need for NCE to have a centralized integrated database to avoid redundancy and increase effectiveness and productivity. The information on this matrix may also may be helpful later on in developing implementation priorities.

The BSP methodology shows information flow within NCE. It displays relationships to modules and subsystems and the processes supported by each subsystem. From these results, information resource decisions can be made. We have demonstrated through our matrices an understanding of processes used by NCE in terms of information needs. With this illustration of grouping of major activities, ownership and usage of information have been analyzed. Through our analysis NCE has been given a starting point to design a centralized database that supports the

DATA CLASS \ SYSTEM	Proposal Preparation	Master Scheduling	Capacity Planning	Material Tracking	Material Information	Material Estimation	Labor Tracking	Shop Order Status	Shop Order Generation	Component Testing	Reliability Engineering	Product Assurance	Part Status	Cost Account	Management Control	Program Cost Review	Weekly Scorecard Status
Engineering Design Specs					X		X			X	X	X			X		
BOM		X	X	X	X	X	X				X	X	X		X		X
Schedule Requirements	X	X	X					X						X	X	X	X
Estimate Labor Hours	X	X	X				X							X	X	X	X
Estimate Material Costs	X		X	X	X	X									X	X	X
Estimate Manufacturing Costs	X														X	X	
Cost Reports															X	X	X
Pre/Fab Releases					X												
Material Due Dates				X	X								X				X
Purchase Order					X								X		X		
Work Package/Planning Package				X			X	X						X	X	X	
Material Receipt					X								X				
Raw Material Description					X	X	X			X	X	X	X				
Inventory					X								X				
Parts List					X				X				X				
Shop Order Request									X								
Parts Kits				X	X			X									
Shortage List								X					X				
Revised Assembly Instructions								X	X		X	X		X			
Shop Order Status									X								
Shop Order								X		X							
Product					X	X	X			X	X	X		X	X		
Test Data								X			X	X					
Test Database											X	X					
Reliability Information																	
Actual Labor Hours				X										X	X		
Performance Evaluation																	X
Project Status														X		X	X
Action Messages					X			X		X							X
Product Standards							X			X	X	X		X			
Production Processes																	
Time Standards			X				X		X					X			
ECN, EHO, etc.					X		X	X	X	X	X	X		X			X
Actual Material Costs				X	X										X	X	X
Master Schedule		X															
Capacity Plan			X					X									

Figure 5.5 Systems/Data Class Matrix

organization's objectives. Because information is a corporate resource, the information architecture design that we have suggested will help them capitalize on its value and implement the most cost efficient and effective system.

J. NCE REQUIREMENT SPECIFICATIONS

Before implementing any system, it is important to have a clear understanding of what is needed in an organization. By interviewing several managers and support personnel at NCE and completing an informational requirements analysis, we have identified some fundamental requirement specifications; particularly within the Operations Organization. Requirement specifications have been defined as a "description of the functions that are to be performed by a system along with the data to be processed" [Ref. 26:p. 77].

We have identified requirement specifications for planning, control, training and support.

The following requirement specifications have been identified for Planning:

- A master schedule within an integrated on-line system with a feedback loop into other computerized programs and an automatic update from cost systems
- An automated master capacity plan including subcontracting techniques
- A consistent contract scheduling system
- A formal schedule-to-performance feedback system
- Time standards for planning or handling functions imposed by the Federal Government for some contracts
- Short and long-range cross-contract inventory control
- Training on project management techniques to be applied to computer systems

The following requirement specifications have been identified for Control:

- A completely integrated manufacturing control system
- An adequate connection between contract material scheduling and customer reporting systems
- An adequate connection between contract schedules and manufacturing schedules for master plans
- A means of measuring procurement performance to schedule (No need date is currently maintained once a PR becomes a PO; i.e., there is no subsequent variance reporting)

- An adequate tracking system of unplanned issues of material to contract
- An adequate tracking of in/out of warranty repair costs by serial number, right now NCE is too dependent on vender status or analyst knowledge
- A formal reporting of physical inventory adjustments to material control to avoid schedule loss due to understated inventory
- A formal reporting of physical inventory adjustments to cost control to avoid understated customer billings
- A regular configuration control of customer in/out of warranty repairs to avoid loss of replacement business
- A centralized way of tracking shop order activity
- A complete communication system that allows feedback to management on areas requiring improvement and formal feedback to design engineering needs to be considered
- An average unit cost calculations including rework

The following requirement specifications have been identified for Training :

- To provide training in manufacturing assembler skills
- To provide training in the use of IBM mainframe software tools
- To provide training in the use of Vax software tools
- To provide training in the use of PC software tools

The following requirement specifications have been identified for Support:

- Project/task management to project complexity ratio needs to be reduced; (i.e., there are too many task managers which leads to confusion for functional organizations)
- Proposal preparations need to be coordinated to avoid redundancy as well as understated and overstated bids, late bidding, and lost bids that may increase contract reconciliation tasks and contribute to lost business

Some management personnel at NCE are aware of the needs and shortcomings of the organization as evidenced by the above requirement specifications. However, unless some of these problems are solved, NCE's management may continue to experience planning, control and scheduling limitations.

The above requirement specifications are the first step in creating a computer integrated manufacturing (CIM) environment at NCE. This environment should provide an efficient and effective integrated interactive on-line computer resource system architecture; a network management and control system; a cost-effective system; a system which is similar to an MIS/MRP II that includes CAD CAM capabilities and is responsive to the needs of a defense contractor "job shop" environment and one that provides managerial decision support; a system which provides security facilities (i.e., one in which users can be defined and identified at various levels of authorization and one that can be enforced); and, finally, a centralized database which provides labor and material tracking and exception information as well as a wide variety of access methods that can provide the flexibility needed for a "job shop" environment.

Our analysis of information system support derived from the BSP methodology together with these requirement specifications provide the foundation for implementing a system to support the Operations Organization at NCE.

VI. INFORMATION SYSTEMS STRATEGIC PLANNING

A. PREVIOUS STUDIES

The situation we have described in the manufacturing environment of NCE is not unusual. The requirements we have developed, almost without exception, have also been described in previous system studies conducted at NCE.

Within the last seven years, there have been at least two major studies done at NCE which focus on the manufacturing system.

In 1979, IBM conducted a manufacturing system planning session which resulted in the identification of significant problems, a proposed logic for solving those problems, a cost-benefit analysis of the solution, and goals to be accomplished. However, the IBM recommendations have never been implemented; apparently due to the costs involved.

Approximately three years later, Hewlett-Packard conducted another analysis of the manufacturing environment. This study came much closer to implementation with Operations management ready to sign a contract. However, when it was discovered that the system was not able to perform an operation that was of vital importance in manufacturing operations, the contract was not signed.

Several vendor packages designed for a 'job shop' environment like NCE have also been reviewed during the last several years none of which have been implemented.

B. DRAWBACKS OF PRESENT ENVIRONMENT

IBM's BSP methodology is very similar to that used in the 1979 study. We identified virtually the same requirements that were developed. The only significant changes that have occurred in the intervening period are the recent (within the last year) implementation of a material management system (MIDAS) and the advent of microcomputers. Of these two changes the use of microcomputers is the most significant.

Since the introduction of microcomputers into NCE Operations, personnel have automated various processes in their manufacturing and management systems. Some of these systems are stand alone and some are networked. Application programs for these systems have been and are being created. However, the use of microcomputers is not the long-range solution to manufacturing's and NCE's needs; rather, they should be viewed as a stopgap measure.

The message for senior management in this development is that there is a perceived inefficiency in information flow within the manufacturing system. Furthermore, the problem is seen by middle managers as serious enough to warrant the expenditure of considerable manhours in the development of computer applications and installation of hardware. There are two ways senior management can react to this message.

One way, is to allow the present situation to continue in which line managers select the course of action that is most convenient for them. The result of which is the development of ad hoc systems designed to solve immediate problems. Another effect of this situation is that senior management is not aware of the cumulative costs in dollars and manhours.

One rationale for senior management not pursuing computer-based manufacturing management methods more aggressively has been that manufacturing meets its cost and schedule obligations 90 percent or more of the time. Senior management has also been adamant that any implementation of an automated system must be matched by a decrease in personnel; a requirement that middle managers have been reluctant to meet.

Linking implementation of an automated system to a decrease in personnel appears to indicate a lack of appreciation for the full potential of automated systems. Certainly an immediate decrease in personnel would shorten the time between implementation and a return on investment, but this approach seems to run counter to NCE's concern for its employees.

Even without immediate personnel cuts, we believe cost benefits would soon be evident due to the efficiency in task execution afforded by the availability of timely information. Personnel reductions may possibly occur but their impact could be reduced through attrition and retraining.

If a comparison of the systems costs developed within Operations over the last seven years were compared with the costs of implementing a system such as the one proposed by IBM in 1979, the results may have shown that the latter system not only would have been more cost effective but also more efficient for a "job shop" environment like NCE.

In our opinion the effectiveness of manufacturing in meeting their cost and schedule requirements is due less to the management system than it is to the people. In this largely manual system that is perhaps not surprising. In particular, there are a few key people who have the talent and experience to make the system work.

These key personnel spend so much time tuning and monitoring the system that they have no time for planning. As a result, improvements to the system are implemented on a piecemeal basis. When this lack of planning time is combined with senior management apathy, what occurs is the patchwork of automated applications and equipment currently being used.

Another drawback of the current system is the lack of information available to managers. Again, this deficiency is due to the time involved for planning. The complexity of the manufacturing environment at NCE, when it is managed using a manual system, requires large numbers of people to monitor various levels of the process. Personnel at each level of the process are concerned with increasing the efficiency of their task. There is little concern or time allowed for producing information in a format that might be useful to managers at different levels.

Within Operations this has resulted in a myriad of reports generated by different organizations, in different formats, and at different times. The existence of these various clusters of data within Operations and the existence of the same type of data in the IM system create a problem known as data redundancy.

The problems of data redundancy normally arise as a result of a historical evolution of computer usage. This certainly seems to be the case at NCE. Isolated and independent applications are selected and mechanized, typically to reduce operational costs. The data files are defined as necessary to support the specific needs of each application without regard to one another or to future applications. The data itself is converted from manual files located and maintained by the using organization.

As computer applications are added, new data files are usually required since the data requirements for different applications are rarely the same. These are usually created from spinoffs of existing mechanized files plus any additional data that may be required.

Summary reports for higher management levels are the result of sorting and merging various existing data files together to create new ones. Rarely is any existing data file of the form or content required to provide newly requested information of any magnitude. Thus, new data files are born. Data redundancies and file update requirements multiply. Most often no one program or individual knows where all the data repositories are located. As a result, updating of information may only affect a few locations.

Obviously, whenever a comparison of output from these different sources takes place there will be discrepancies. To determine the reasons for these discrepancies, an investigation is conducted. All of this tends to negate some of the efficiency afforded by automation. In Operations, this can be particularly critical since conflicting data can mask indications of trouble in a project and the time taken to discover the reasons for the discrepancies may delay the implementation of corrective actions. Another facet of the multiple report problem is that the data needed to determine a program's status is spread across several reports. This leads to another use for PCs; recompiling data from several applications into a usable form.

The alternative to the current system is the other approach we alluded to earlier which would entail a plan for the development of an information system architecture and an accompanying plan to guide its implementation at NCE. In this approach, senior management would guide the development of systems and ensure the most cost effective use of resources.

Whether the plan calls for the introduction of a manufacturing information system or enhancements to the current system, it would provide guidance to mid-level managers. This guidance would ensure that manufacturing applications and systems are developed with integration as the company's main goal. This plan may also help to minimize the occurrence of data redundancies and streamline system software and hardware while increasing their efficiency and usefulness.

Such a system would reduce the company's dependence on a few key people and tend to institutionalize knowledge in the system. The support that this plan would have from senior management would facilitate obtaining support from IM system personnel in the development and implementation of manufacturing oriented systems. This would allow manufacturing personnel to spend more time on their primary mission.

While such a plan may seem to carry with it the potential for lengthening the implementation process, the tradeoff is a system that is integrated with other elements of the company's information system. This should result in increased efficiency in the company's business processes and certainly should ensure that long-range company strategies are considered.

We believe that senior management's apparent satisfaction with the performance of the current system and the emphasis on reducing personnel levels may be a symptom of a more fundamental problem. This problem has as its source the company's view of the Operation's managers. The average tenure for the last few Operation's managers have been four or five years.

There are indications that this position is considered by the company as not being particularly important. Because of this, managers of Operations have been oriented to short-term solutions. Certainly, under these conditions, any proposal to spend a significant amount on a manufacturing information system would be scrutinized carefully and immediate results such as personnel reductions would be expected.

In addition, the installation time and learning curve that would be necessary with such a system may lead managers to believe that they will be saddled with the costs while not being around to see the results. The issue is not whether this perception of the position is correct or not, but that an architecture and plan would remove this problem by establishing a company requirement for the system. Thus, the Operation's manager could proceed with implementation without concern for the repercussions.

C. TECHNOLOGICAL EFFECTS

Information Systems (IS) are increasingly moving toward user-dominated technologies. As these technologies enable IS to be applied to a wider spectrum of business problems, increasingly larger segments of a company are placing demands on the IS resource. This evolution in IS is having two effects; first, as more business units of a company employ the IS resources it becomes more important that this resource be independent and managed as a company-wide resource. Failure to do this, almost inevitably will lead to alienation of some users who perceive bias on the part of the IS resource toward the organization that controls it. With the alternatives in IS technologies available today, this can turn into an expensive problem.

Within NCE, an example of this situation has occurred in the Operations organization. The perceived non-responsiveness of the IM organization to Operation's IS needs has resulted in the acquisition of large numbers of PCs and the development of a considerable number of independent applications. These are used to perform tasks that Operations sees as critical to the efficient accomplishment of its mission.

The cost of the approximately 130 PCs that are in place and on order can be estimated fairly accurately. What is more difficult to estimate is the number and cost of the manhours spent developing the applications that are used. The point is that these costs and manhours might have been spent more effectively had some company strategy for the use of IS resources been in effect.

The second effect of the evolution in IS development, is information sharing on a company-wide basis. As increasingly larger segments of a company find that an IS resource can help them in their work, the advantages of information sharing become evident. As more information is placed in the system, greater efficiency in the business becomes possible. Information generated by one part of the business and needed by another can be instantly available. Instead of transmission by phone or document, information can be placed in a central location and manipulated as necessary by different organizations using different applications. This is possible through the use of tools such as databases.

In this discussion of information sharing, databases and efficiency, there are mixed the important qualifiers "can be" and "possible". The existence of an IS does not automatically mean that information sharing and efficiency follow. The presence of incompatible hardware and software can render information sharing difficult and efficiency limited to individual processes.

At NCE this is evident in two situations. The first concerns the engineering directorates and Operations. The engineering directorates provide most of the information that Operations needs to perform its mission. However, the engineering directorates are primarily tied to the VAX while Operations is a customer of the IM system. The result is that very little information that Operations needs is available via the IS at NCE. There is no standardization of how or what information in projects is transmitted to Operations. Thus, with 24 program offices each doing business a different way, it is difficult for Operations to efficiently manage the approximately 500 programs they work on each year.

In addition, there is considerable difficulty in receiving timely information on changes that have occurred in the project specifications and or schedule. This cannot help but result in inefficiencies in Operation's activities. There seems little doubt that access by both Operations and the engineering directorates to a common database containing information on programs would lead to standardization in program office dealings with Operations and increase efficiency in the Operations area.

The second situation concerns the applications supported by the IM system and used by Operations. In many cases, applications that produce information that Operations need use databases that are incompatible. This results in the production of reports that contain similar information but in different formats. The inability of any one of these applications to produce a report with all of the information that Operations needs to manage a program means that they must extract some information from each report and recompile it on their locally developed PC applications. This process usually results in inconsistencies in reports generated by different departments and different systems.

The move toward information sharing on a company-wide basis is another reason for the establishment and enforcement of a company-wide IS strategy. A policy needs to be established which will guide the development of databases and applications to ensure that they will produce information that is usable and accessible to all elements of the company that need it. This will ensure not only that resources are used as efficiently as possible but that data integrity is facilitated.

The implementation of a manufacturing information system associated with changes in corporate planning that we have discussed to make it [illegible]

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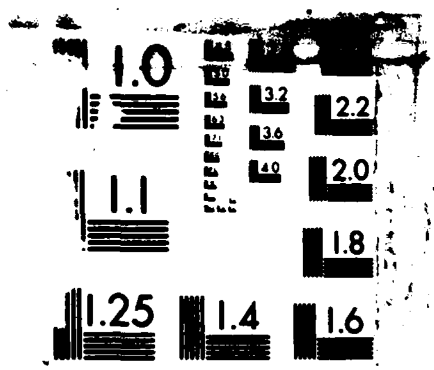

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can be viewed as strategic change in an organization such as NCE. However, even the most technically correct system will not succeed if the organization is not properly prepared. There are three dynamics which operate in all organizations; technical, political, and cultural. These dynamics must be considered when implementing any changes. [Ref. 27:p. 118]

The argument has been made that organizations attempt either to reduce or manage uncertainty. Examples of uncertainty affecting the three dynamics mentioned above include uncertainty about market, production capability, and technical innovation; uncertainty about candidates for success, power distribution, and the politics of reward allocations; and uncertainty about the appropriate value system for the organization, or the existence of conflicting value systems.

Once uncertainty in any one of these systems is perceived, a response is triggered. At that time managerial problem-solving attention is invested in either reducing uncertainty or determining how to cope with it.

Uncertainty creates a need for adjustment. In the situation being discussed, uncertainty might be triggered in the technical system by the implementation of a manufacturing information system. Furthermore, the implementation of strategic IS planning along with the authority to enforce it might be expected to create uncertainty in the political system. Uncertainties in these systems may trigger a reaction in the cultural system as well. However, recognition of these factors by management and taking the proper steps to minimize their impact can result in a smooth transition to the new methods.

Managers should realize that there are organizational forces that may result in resistance to a new capability no matter how well designed it may be. These forces can be anticipated and with proper planning and implementation, be reduced and/or managed.

D. SUMMARY

The situation at NCE is not unique. The evolution in computer technology has created similar situations in thousands of businesses. Middle management is trying to increase their efficiency and in the absence of any guidelines or corporate/company IS strategy they are using the resources available to them.

Senior management at NCE have recognized the need for centralized strategic IS planning. They have designated the chief of the Digital Technology office the GM's advisor on company computer architecture planning. However, recognition has not yet resulted in effective strategic IS planning. Senior management does not seem to have embraced a company strategy and established a position with the requisite authority to oversee its implementation. Yet the conduct of IS planning can be crucial:

> There continues to be evidence that there is a clear link between effective planning and effectively perceived IS activity for many organization settings...a major role of the IS planning process is stimulation of discussion and exchange of insights between the specialists and the users. [Ref. 28:p. 231]

Some guidelines for effective IS strategic planning are also crucial:

> As organizations grow in size, complexity of systems, and formality, IS planning must be directly assigned to someone to avoid resulting lack of focus and the risk of significant pieces dropping between cracks...The task is to ensure that planning occurs in an appropriate form. A strong set of enabling and communication skills is critical if the individual is to relate to the multiple individuals and units impacted by this technology and cope with their differing familiarity with it. Ensuring involvement of IS staff and users for both inputs and conclusions occurrence is key.
>
> Planned clutter in the planning approach is appropriate to deal with the fact that the company is in different phases with respect to different technologies and the technologies have different strategic payout to different organization units at different points in time.
>
> IS planning must be tailored to the realities of the corporate style of doing business. Importance and status of the IS managers, geographic placement of IS in relation to general management, corporate culture and management style, and organizational size and complexity all influence how IS planning can be best done.
>
> The planning process must be considerably broader in the range of technologies it covers than just data processing. It must deal with the technologies of electronic communications, data processing, office automation, stand-alone minis, and so forth, both separately and in an integrated fashion. [Ref. 28:p. 232]

The implementation of a manufacturing information system and/or the changes to company IS planning that we have discussed will almost certainly be a traumatic experience for some elements of NCE. These changes may affect the technical, political, and cultural dynamics of the company. To minimize the disruptive effects of the changes and reduce resistance, the development of a strategic change plan is recommended.

VII. CONCLUSIONS AND RECOMMENDATIONS

The present manufacturing/assembly system, although a tedious mostly manual process, is allowing Operations to survive and meet their objectives of quality, cost, schedule, and responsiveness to customer needs. However, they are conducting business in a reactive mode rather than a proactive mode which is difficult to accomplish in a diversified job shop environment. Operations management attempts to smooth out peaks and valleys that occur not only with cross-training of personnel, but also by keeping manufacturing and assembling of critical items in-house. However, long-range strategic planning may be possible within a MIS designed specifically for a job shop environment.

We believe there are sufficient indications of potential for marked enhancements in the efficiency of manufacturing operations to warrant the serious evaluation of several software packages for their ability to meet the requirements developed in this document.

It is important that the users of this application be intimately involved in the evaluation process. It is also important that this application be evaluated in terms of integrating it with the company's other IS resources. As an example, some of Operation's problems will continue even with implementation of a new manufacturing information system if the engineering directorates are not linked with the system. Such a link would also serve to demonstrate the need for standardization of program management practices as they affect interaction with Operations.

An efficient computerized system which includes master scheduling, labor and material tracking, material costing, and a DSS for managers would be an asset for Operations. Even though the Drafting Department is presently using a CAD/CAM system, additional productivity gains could be achieved through the use of upgraded CAD technology.

A policy for the use of PCs should be developed to ensure that they are not being used to circumvent use of mainframe applications on a large scale. If this is detected it serves as an indication that the policies affecting mainframe usage need to be re-examined. Unfortunately, stand alone proliferation of PCs using independent databases is not desirable for reasons of data integrity and data security. Also, PCs do not satisfy the need for sharing information because they encourage isolation; nor, do they necessarily provide the proper tools to get some jobs accomplished efficiently.

A total Information Center that can provide the expertise and information needed by end users (whether in the IM, Vax, OES, PC environment), would be very effective in helping to minimize isolation. The location of the IC, of course, would be a strategic decision; and, one that could lead the way to a more centralized environment. However, to be most efficient and effective, control of the IC would have to be be determined by top management.

Digital Systems supports IM's Information Center concept. However, as a step toward centralization, IC should include not only IM's resources, but also the resources and expertise of personnel within Engineering and OES to enrich system functionality. A total systems architecture would include business plans, business operations, user functions, user interface, existing environment, technology, productivity potential, and affordability.

The cost of doing business within Operations must be lowered in all areas. Operations supports 500 programs a year of which 70% is five programs and 30% is the remaining 495. The key areas involved in keeping costs down are the lowering of labor rate bases and the lowering of overhead rates. To lower labor rates, Operations is hiring lower classified personnel when job vacancies occur. Also, the head of Operations has been instrumental in cross-training of personnel offering the ability to transfer personnel to other areas when a slack exists. In addition, lowering the overhead rate could be accomplished through the introduction and use of new technologies.

An overview of current and future programs within Operations indicates that the mix of programs is expected to change toward more software driven systems utilizing equipment with subcontracted hardware parts and assemblies. Since the material content of Operation's programs amount to about 30 percent of NCE's sales, it must have prudent procurement and timely delivery of a high quality product. Vendors should be dependable and fairly priced. Areas need to be investigated for improving procurement, material handling, distribution, and inventory, if NCE is to maintain and improve their competitive edge. New MIS need to be evaluated to minimize the time from requisition to receipt of material.

Due to the efficiencies in business processes that are possible with current technologies, strategic IS planning is becoming increasingly important. The installation of an MIS will enhance Operation's performance of its mission. But NCE will only realize the maximum benefits from this system if it can be integrated with future systems. Planning and policy development will ensure this.

The best system devised by man will not succeed if the organization is not properly prepared for its implementation. Viewing information as a corporate-wide resource and developing the means to manage it through the creation of a strategic IS plan with someone to oversee activities, amounts to strategic change in an organization such as NCE. This requires preparation of a strategic change plan to minimize resistance in the organization caused by implementation of new methods.

This thesis is an initial attempt to describe the computer resources, organizational structure, informational flow of the project and manufacturing processes within the Operations Organization, as well as the development of requirement specifications. It is designed to be a starting point: a foundation on which future theses can build. Areas for further research include a comparison of various vendor MIS/MRP II systems as well as a cost/benefit analysis of the various vendor systems.

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